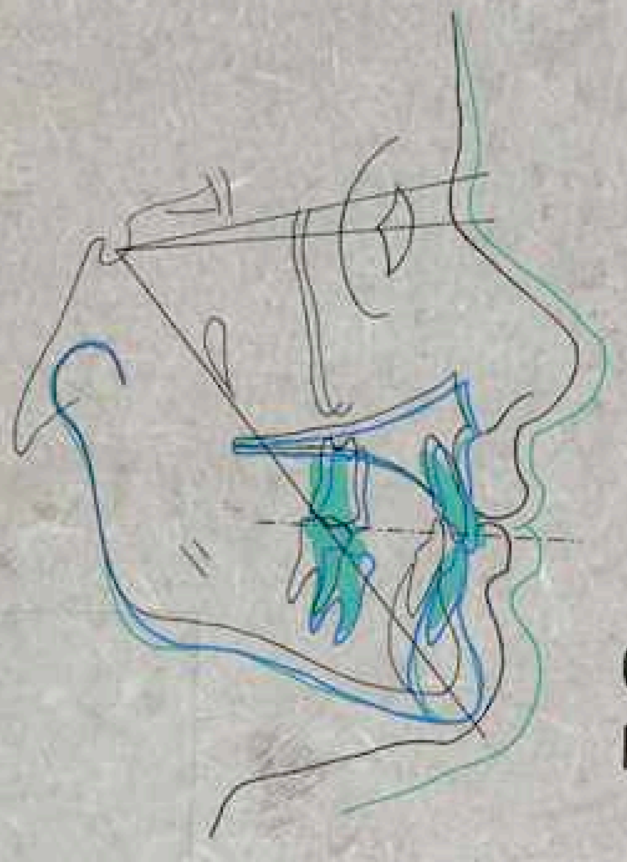
Problem Solving in ORTHODONTICS

Goal-Oriented Treatment Strategies



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Contents

Preface

The field of orthodontics is in the midst of a knowledge explosion: we've seen a proliferation of new books and journals, new appliances, space-age materials, and new diagnostic and treatment modalities. Basic and applied research have more clearly defined the biology and physics of dentofacial modification, while controlled clinical outcome studies are delineating new treatment possibilities and limitations. This book addresses two key questions: Are older goals and strategies obsolete? Is a new paradigm needed?

To institute realistic goals and effective mechanotherapy, clinicians require clear and unequivocal answers to situations they routinely face. Can orthopedic effects be obtained in the maxilla and mandible? Can arches be stable if expanded? Can lower incisors be flared, and what is their optimal position? What is the role of molar distalization in Class II correction? *Problem-Solving in Orthodontics: Goal-Oriented Treatment Strategies* provides simple, practical, and concise answers to these and other significant questions. Its chief aim is to describe—in a scientific context—the tools required by both the novice and the experienced clinician for treating challenging malocclusions. Since treatment goals, strategies, and sequence must be defined before appliance therapy can begin, this book does not advocate the use of a specific appliance.

The major steps involved in the development of pleasing facial and dental esthetics, normal dental health, and stability of the dentition include (1) a description of an orthodontic database and its analysis, (2) the development of a patient's problem list, (3) determination of general treatment goals with more specific treatment objectives, and (4) design of the specific mechanotherapy needed to reach these goals. Numerous texts describe malocclusions and classifications and consider only diagnostic criteria (step 1). Others present a given technique or techniques without addressing treatment goals (step 4). This book is unique because it describes the steps involved in defining treatment goals and objectives, and it documents the goals in three dimensions. These three-dimensional treatment goals are derived from a thorough analysis of the orthodontic database and the creation of the patient's problem list. Orthodontic mechanotherapy can be designed to achieve these treatment goals rather than being merely a stepwise progression through a given technique. When the additional variables of time (growth) and function are considered, the approach becomes truly five dimensional.

The sequence of the chapters reflects the recommended sequence for orthodontic goal determination. Thus, the first step is to determine the planned changes, if any, in the facial skeleton; step 2 shows how the cant and level of the treatment occlusal plane can be established; step 3 shows how to develop the arch form, arch widths, and so forth. All concepts and procedures are demonstrated by well documented clinical cases presented in three dimensions (tracings of the lateral and posteroanterior headfilms and occlusograms). The remaining chapters synthesize the concepts and approaches by applying them to difficult cases with well documented records. Although the use of simplistic cephalometric standards as a treatment goal is rejected, longitudinal dental and skeletal standards are provided in the appendixes.

This book goes beyond diagnosis in developing a scientific and biologic basis for clinical orthodontics. It emphasizes nonsurgical orthodontic treatment and includes important factors in differentiating extraction from nonextraction treatment. Because it does not emphasize one particular technique, it is useful to all orthodontists who wish to establish meaningful goals before designing, selecting, or using a particular appliance.

1
Chapter

Introduction to Three-Dimensional Orthodontic Treatment Planning

Orthodontics has evolved from limited treatment goals, such as "normal tooth alignment," to the current three-dimensional concept of tooth and bone position and the establishment or reestablishment of normal jaw function and good facial esthetics. But before orthodontic therapy can begin, it is imperative for the orthodontist to have a sound idea of where the orthodontic treatment should lead, ie, specific treatment objectives for each patient. From these individualized treatment objectives, appropriate appliances and biomechanics can be designed and used.

The primary emphasis of this book is on proper orthodontic diagnosis and treatment planning and, secondarily, on the biomechanics of treatment. Our failures in treatment and postretention are often related to poor mechanics but, in a high percentage of cases, errors can be found in how we determine a patient's treatment objectives.

Medical Versus Orthodontic Treatment Models

In disease-oriented disciplines such as medicine and dentistry, the idea of treatment planning and eventual treatment is based on the identification of disease. A database is obtained and, based on this database, the disease is identified and the available treatment options considered (Fig 1-1). Bacterial cultures, for example, can be taken on a patient and, based on these cultures, the disease organism identified and a proper antibiotic regimen initiated.

In the craniofacial aberrations called orthodontic malocclusions, one is not really describing a disease; only rarely is malocclusion involved with frank pathology. Most malocclusions are the result of normal skeletal and dental variations and, when these variations become extreme enough to disturb the patient esthetically or functionally, orthodontic treatment is warranted.

There have been attempts to apply the medical model of disease identification to orthodontic treatment planning. Some of the original classifications, such as the Angle classification, were based on the maxim "treatment follows classification." Thus, all patients with a Class II, division 1 malocclusion were treated alike, as were all patients with a Class III malocclusion. The futility of treatment based on classification is obvious; regardless of how detailed a classification is, it is not explicit enough to distinguish the multitude of treatment objectives among individuals.

Database → Disease identification → Treatment

Fig 1-1 Disease-oriented sequencing of treatment.

Records and clinical exam

↓

Database

↓

Analysis and synthesis

↙ ↘

Problem list | Classification

↓

Treatment goals

↓

Sequence of treatment

↓

Biomechanical planning

↓

Appliance design

↓

Appliance use

Fig 1-2 Orthodontic treatment sequencing. Note that treatment is not determined by classification.

The sequence of orthodontic diagnosis, treatment planning, and therapy is summarized in Fig 1-2. The orthodontist collects records, including dental casts, a clinical examination, facial and intraoral photos, and various radiographs. Of particular importance is a thorough clinical examination, since this will give information not found in any of the permanent records. From the records and the clinical exam, a database is established. This database can be examined either quantitatively or qualitatively. A headfilm, for instance, can be traced and measured for specific cephalometric measurements (quantitative), or a nonnumerical judgment can be made based on a visual examination of the radiograph (qualitative).

As the patient's database is gathered, it is possible to learn much about the patient by separating the database components and analyzing them individually, ie, the step of case analysis. With the study casts, for example, it is possible to measure the patient's arch widths to compare them to the average values or standards. From an analysis of the patient's cephalometric radiographs, it is possible to determine if the maxilla is too large or if the mandible is too small or if there are positional abnormalities involving bones and/or the teeth.

It is not enough to measure and analyze in detail all of the craniofacial and dental aberrations. One must make sense of these measurements, which requires that the data be assembled or synthesized in a way that enables one to answer a number of clinically relevant questions, such as: Why is there a Class II? Why is there a Class III? Why is the right side Class II and the left side Class III? Why is there a deep overbite? What produces the crowding or the spacing? The answers to these questions require that all of the patient's data be synthesized. The synthesis may then show that the position of the patient's maxilla or mandible is too far forward or too far backward or that the patient's teeth alone are responsible for the malocclusion. From this synthesis of the data, a patient's problem list can be developed.

The Problem List

What is a problem list? It is not just a listing of the database findings; it is a list of the clinical symptoms that affect the health and well-being of a patient. For example, incisors that are protrusive by cephalometric standards may or may not appear on the problem list. If the protrusive incisors are not responsible for any facial or functional problems, an abnormality may be present, but it is certainly not a "problem." Confusion and overtreatment can arise when every abnormality is listed as a problem. Skill and judgment are required to determine when a clinical abnormality becomes a clinical problem. Because craniofacial variation is not a disease, some variation is acceptable and expected.

When the problem list becomes significant to the patient, treatment is elected. The orthodontist then determines the patient's treatment objectives. This step includes determining the positions of the teeth, bones, and facial soft tissues in three dimensions over time. These objectives must also address jaw function and the elimination of undesirable etiologic factors. Much of this book will be devoted to these various treatment objectives, which may include achieving desired skeletal changes in the craniofacial skeleton, altering the position of the occlusal plane, deciding on the best arch form and dimension, determining the anteroposterior position of the incisors, establishing a treatment midline, and deciding on the methods to solve the arch length inadequacy or redundancy.

Treatment Sequencing

Once these treatment objectives have been determined, the orthodontist can establish the treatment sequence, ie, the step-by-step progression of treatment. For example, for a patient requiring extraction of the upper first premolars, the orthodontist should determine whether the upper canines should be retracted first or whether the intrusion of the upper incisors should be first accomplished and then all six anterior teeth retracted.

Treatment sequencing can be an exciting part of orthodontic treatment planning; it can be highly creative. The selected treatment sequence is very important in minimizing undesirable side effects during treatment, in maintaining anchorage, and in reducing the time of treatment and tissue damage.

Following the establishment of the treatment sequence, the next important step is to design a sound mechanical plan to accomplish the treatment objectives. This mechanical plan should include the kinds of tooth movement involved, the necessary force systems required for the necessary tooth movement, the equilibrium states produced by these force systems, and the best mechanisms to deliver these force systems. Once the optimal appliances have been chosen, the necessary design and activation can be outlined in the mechanical plan.

Only after a careful work-up (records, database analysis, synthesis, problem list, treatment objectives, treatment sequencing, mechanical planning, appliance selection, and the determination of appliance force systems) do the appliances themselves come into play. It is unfortunate that many orthodontists are "appliance oriented"; for them, time spent on treatment planning is minimal. Instead, sequences of arches are suggested for different types of patients with little thought given to the patient's treatment objectives, the proper sequence of treatment, or the biomechanics of appliance design and use.

No matter how well treatment planning is carried out, surprises can occur. It is for this reason that many orthodontists devote little time to diagnosis and treatment planning, believing that the treatment plan will never be carried out as designed. One might draw an analogy between sending a rocket to the moon and orthodontic therapy. When sending a rocket to the moon, a "straight shot" is sought, with minimal deviation from the flight path. In the real world, however, a rocket guidance system may not be perfect and the rocket may veer off to the right and to the left in varying amounts. But, for every deviation, ground control can still correct the rocket's flight path so that its average course is still directly to the moon. Thus, to successfully send a rocket to the moon, monitoring of the rocket's position at all times is required. Of course, the better the "rocketry" (biomechanics) and the better the navigational plan (treatment sequencing and mechanics plan), the shorter the trip (treatment

time) and, hopefully, the smoother the landing (less tissue damage) when the rocket finally reaches the moon (treatment objectives).

There are a number of variables over which the orthodontist does not have direct control, including patient cooperation, growth, and the efficiency of the appliances. It is for this reason that orthodontists should monitor their patients' progress throughout treatment, clinically at each appointment and periodically with the use of "progress headfilms." Such close monitoring allows the orthodontist to adjust and reorient treatment in order to reach the patient's treatment goals, recognizing that there may be deviations throughout the course of treatment because of noncompliance, appliance deformations, missed appointments, and unusual growth. Close monitoring of a patient's treatment also means flexibility. If new information presents itself and the orthodontist believes that there is a need to change the patient's treatment objectives, it is possible to do so midway during treatment.

Establishing Valid Treatment Objectives

The characteristics of a good treatment objective are that it be beneficial to the patient, measurable, and achievable.

Patient Benefit: Historically, there has been a tendency for orthodontists to treat to means or standards. Means or standards are applicable only if they benefit the patient. In many instances, treating to a mean or an average would mean moving teeth in a direction opposite to what would be a desirable therapeutic endpoint.

How does one determine what is of orthodontic benefit to the patient? Five guidelines can be used: (1) facial esthetics, (2) dental esthetics, (3) dental and oral function, (4) stability, and (5) longevity of the dentition. If a patient has a lower incisor at 50 degrees to the Frankfort horizontal and the cephalometric standard is 65 degrees, is therapy indicated? Only if the patient would benefit from this type of tooth movement, either by improved facial esthetics or improved function or perhaps by overall stability of the dentition.

Because orthodontics deals with biologic variation, one of the most difficult aspects of making decisions in the treatment-planning process is the realization that treatment objectives may not be mutually compatible. The positioning of the teeth for optimal stability and longevity may not necessarily result in a pleasing facial appearance. The limited knowledge available regarding an optimal gnathostatic system further complicates orthodontic decision-making. For instance, the optimal dental arrangement for maximizing temporomandibular joint health is not known; neither is the most-stable posttreatment position of the teeth known, nor whether this position of the teeth will result in the best facial esthetics. In short, good functional and esthetic occlusions may have anatomic differences from patient to patient, and orthodontists should refrain from treating patients to cephalometric standards or means. Doing so would limit the array of treatment options and not necessarily benefit the patient.

In contemporary medical practice, no longer does the provider alone decide the plan of treatment. An increasingly well-informed public wants to participate in deciding treatment goals and therapy. This is particularly true in orthodontics, which has an important esthetic component. When the treatment objectives are compatible with the patient's perceived needs, treatment success is enhanced. Consider the patient for whom 5 mm of upper incisor retraction is stated as a treatment objective. This patient perceives herself as having severely retrusive lips, and she realizes that 5 mm of incisor retraction will actually worsen her lip retrusion. The severe anchorage requirements, combined with her deep overbite, will require her to use a headgear as much as possible during the retraction period. Will this patient will be as cooperative as a similar patient in whom 5 mm of upper incisor retraction will reduce her severe lip protrusion, which she perceives as a desirable treatment goal?

Measurability: Meaningful objectives should be specific, measurable, and clearly articulated. It is not enough to plan to "upright lower incisors." How much and around what center of rotation?

With a specific treatment objective of 3.0 mm of lower incisor retraction, the orthodontist can make the best decision as to how to optimally

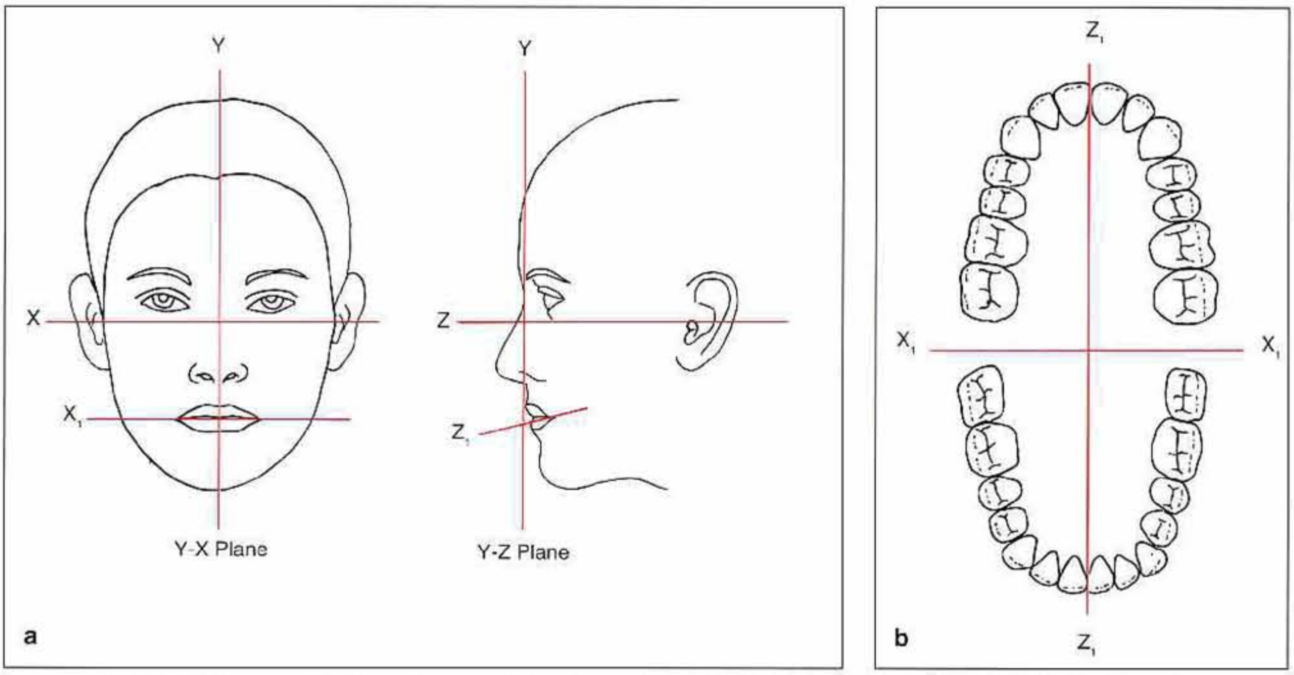


Fig 1-3 The coordinate system used for three-dimensional treatment planning. (a) The horizontal axes form the horizontal plane. This plane is parallel to the Frankfort horizontal plane. The Y-axis is a midline axis through hard or soft tissue nasion or a midglabellar point. (b) The occlusal view, the X_1-Z_1 plane, is usually not perpendicular to the Frankfort horizontal plane. A perpendicular projection of the X-Z plane can be obtained with a submental vertex radiographic image.

retract these teeth, which teeth to remove, and how to manage the resulting anchorage. Also, during and after treatment, the orthodontist can measure how well the stated objective was reached.

Achievability: Unfounded expectations of extensive orthopedics or tooth movement can lead to long treatment times and even failure. When treatment goals are realistic, they are valued by both the orthodontist and the patient; both will exert their fullest efforts to achieve such goals. For treatment goals perceived by either the orthodontist or the patient as unrealistic, treatment success is unlikely.

Three-Dimensional Planning and Visualization

To be more precise in establishing orthodontic treatment objectives, it is useful to have tracings in three dimensions, where the original teeth, the bones, and the facial soft tissues are shown in the pretreatment and posttreatment positions. This visual representation of treatment helps the orthodontist avoid surprises during treatment since the actual treatment can be visualized on the treatment-plan tracings. These initial tracings also provide a basis for comparison with progress tracings as well as a comparison with the posttreatment tracings. This final evaluation is of utmost importance in establishing a retention plan.

Because orthodontic treatment is three-dimensional, proper treatment planning requires three tracings: the lateral view (the Y-Z plane) made from the lateral cephalometric headfilm, the frontal view (the Y-X plane) made from the posteroanterior cephalometric headfilm, and the occlusal view (the X_1-Z_1 plane) made from the occlusogram, a 1:1 photo of the occlusal aspect of the dental casts (Fig 1-3). It must be remembered that the X_1-Z_1 plane usually lies at an angle to the X-Z plane, which is parallel to the Frankfort horizontal.

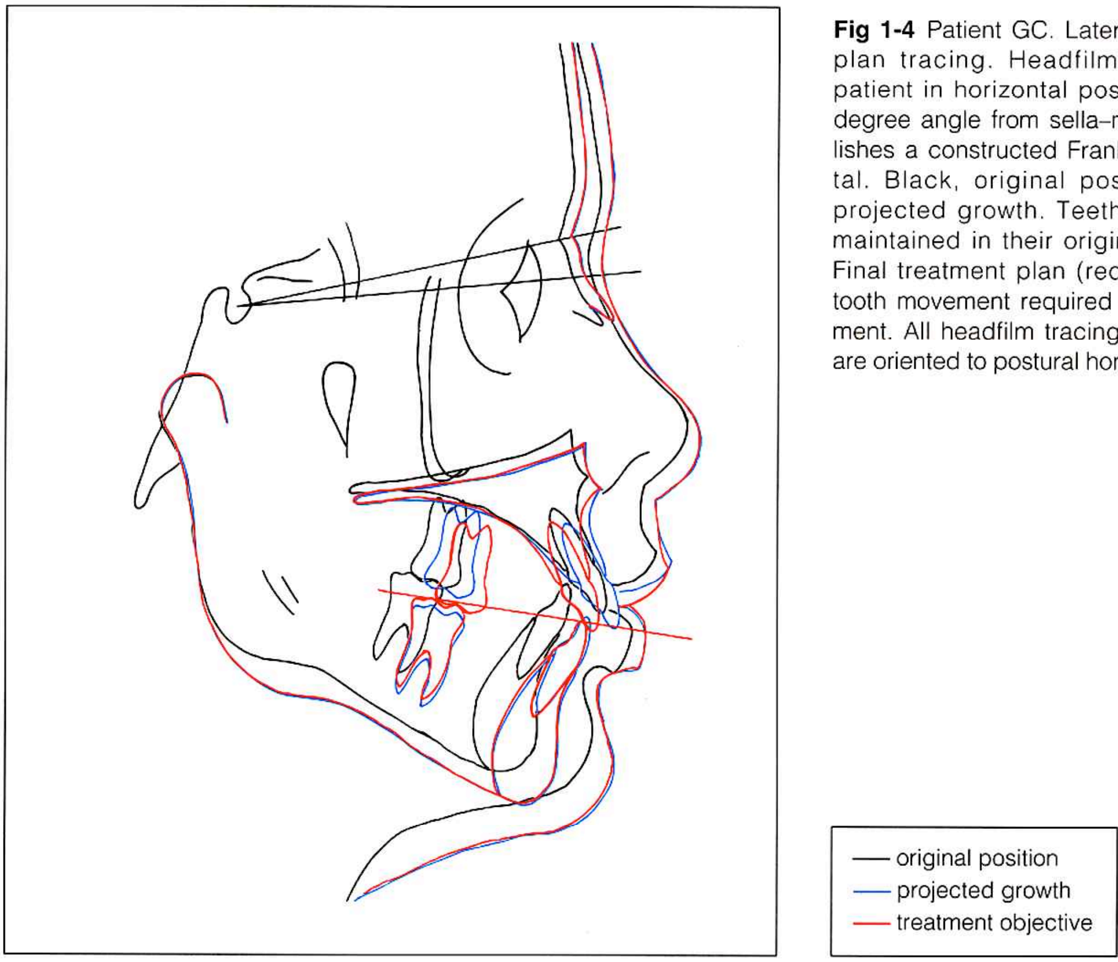


Fig 1-4 Patient GC. Lateral treatment-plan tracing. Headfilm taken with patient in horizontal posture. The 7-degree angle from sella–nasion establishes a constructed Frankfort horizontal. Black, original position. Blue, projected growth. Teeth have been maintained in their original position. Final treatment plan (red) shows the tooth movement required during treatment. All headfilm tracings in this text are oriented to postural horizontal.

The three-dimensional treatment objectives of patient GC are shown in three tracings (Fig 1-4). The lateral view, the Y-Z plane, displays the original tooth and bone relationships (black), the growth prediction (blue), and the final tooth position (red). The occlusogram shows the planned treatment in the X_1-Z_1 plane (Fig 1-5). The original tooth position is shown in black (Fig 1-5a). First, the final arch form is determined; this is shown as a red line through the incisal edges and the tips of the buccal cusps. The inner gray arch connects the future contact areas of the teeth. Then the treatment midline is established (Fig 1-5b); this is shown as a vertical gray line at the incisors. The mesiodistal diameters of the teeth are marked off on the inner gray arch so that the arch length inadequacy can be determined. The distance between the original mesial of the first molar and the horizontal gray line is a direct measurement of the arch length inadequacy. After determining an arch length inadequacy for each quadrant, the decision is made to extract upper first premolars. The new mesial-distal contact areas are marked. It can be seen that the buccal segments must move forward about 3.0 mm in the upper arch (Fig 1-5c). The distance between the horizontal red line and the original first molar position (black) shows the amount of mesial movement that is required of the molar.

Fig 1-5 Occlusal treatment-plan tracings using an occlusogram, made from a 1:1 tracing of a photograph of the original study casts. Median palatal raphe is used as a reference plane.

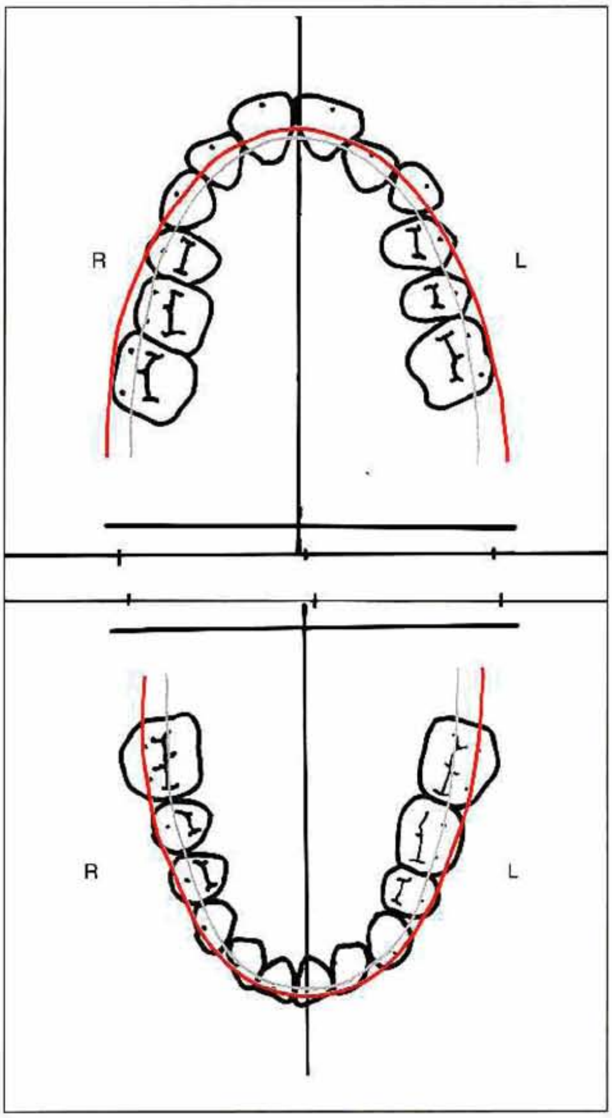


Fig 1-5a The planned arch form through the tips of the cusps and the incisal edges (red line) and the contact areas (gray line). Upper and lower arch forms are coordinated.

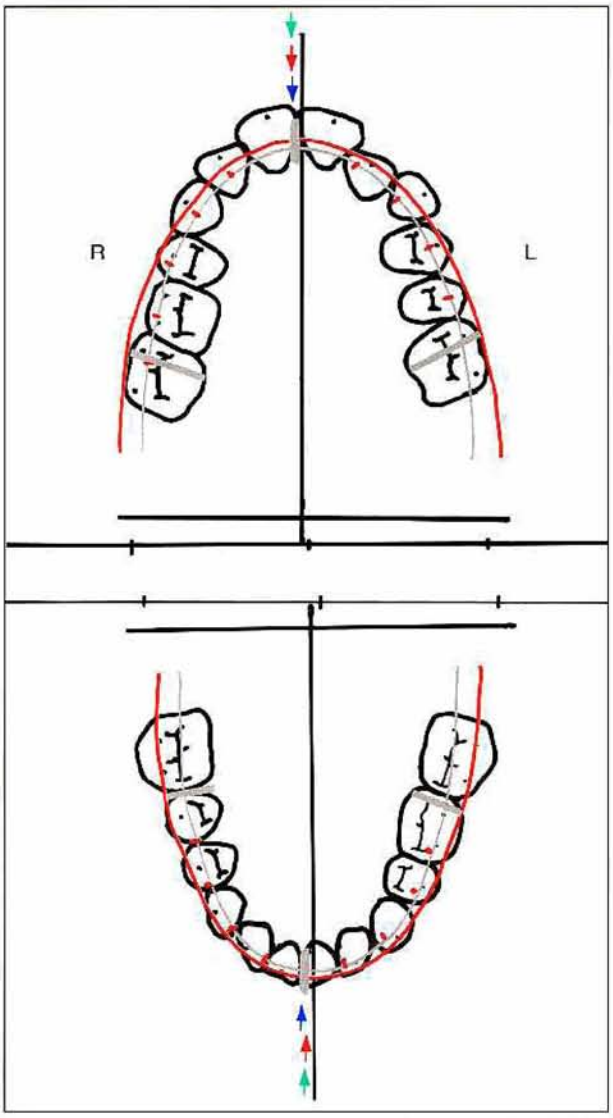


Fig 1-5b Next, the treatment midline is determined. The facial midline (red arrow), apical base midline (blue arrow), and posterior midline (green arrow) are used as guides. From the treatment midline the mesiodistal diameters of each tooth are marked on the arch. The horizontal gray bar is the mesial of the first molar. Measuring from the mesial of the first molar to the gray bar gives the arch length inadequacy or redundancy.

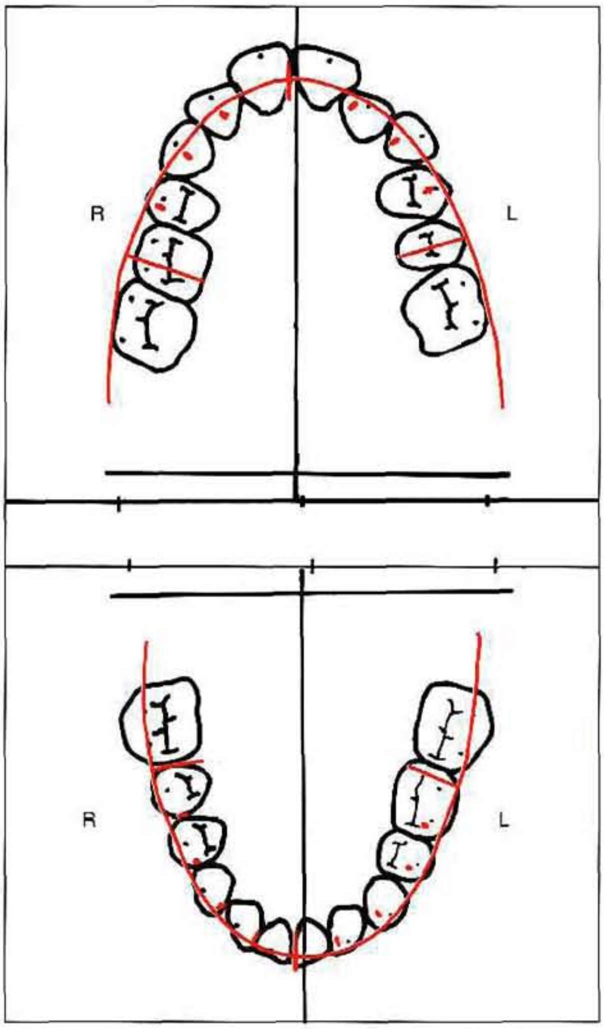


Fig 1-5c Final occlusogram tracing showing the planned position of the teeth. The horizontal red bars represent the new position of the mesial of the first molars.

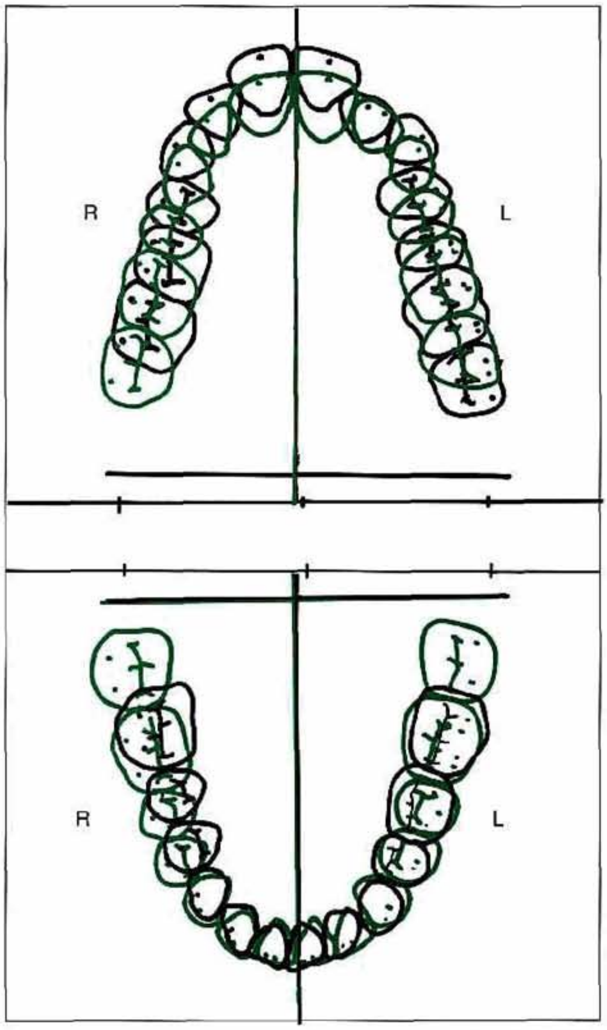


Fig 1-5d Actual treatment changes. Black, initial malocclusion. Green, treatment outcome. Treatment objectives were achieved, with the exception that the midlines are slightly to the left.

Figure 1-6 shows the frontal view (Y-X plane) originating from the posteroanterior headfilm. Planning in this view is helpful for midline determination and the establishment of a desirable transverse plane of occlusion. This view is particularly important in the treatment planning of orthodontic asymmetries requiring orthognathic surgery. (The use of these tracings in achieving orthodontic treatment objectives and the concepts for making valid decisions are described in detail in the subsequent chapters.) The treatment results (Fig 1-7; see also Fig 1-5d) approximate the treatment objective, which was to reduce the patient's lip protrusion. Compare the before and after facial photos (Figs 1-8 and 1-9), the pre- and posttreatment dental casts (Figs 1-10 and 1-11), and the 2-year post-deband casts (Fig 1-12).

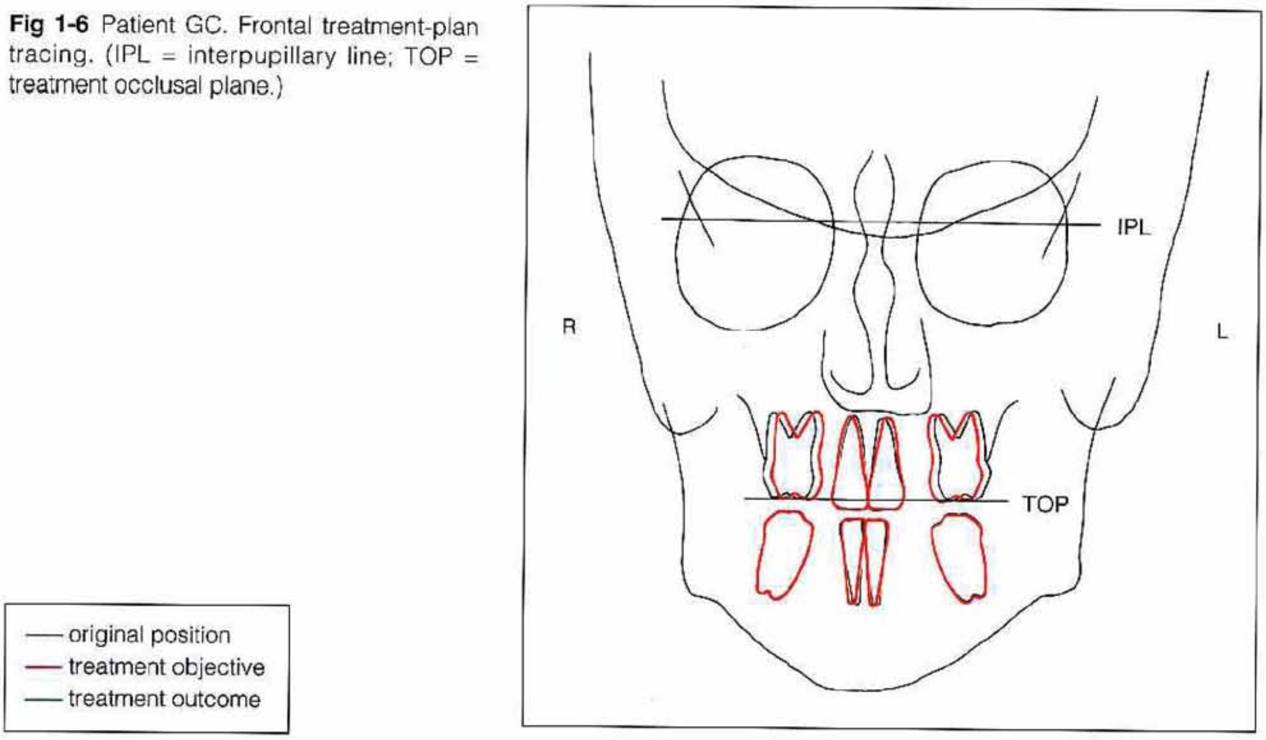


Fig 1-6 Patient GC. Frontal treatment-plan tracing. (IPL = interpupillary line; TOP = treatment occlusal plane.)

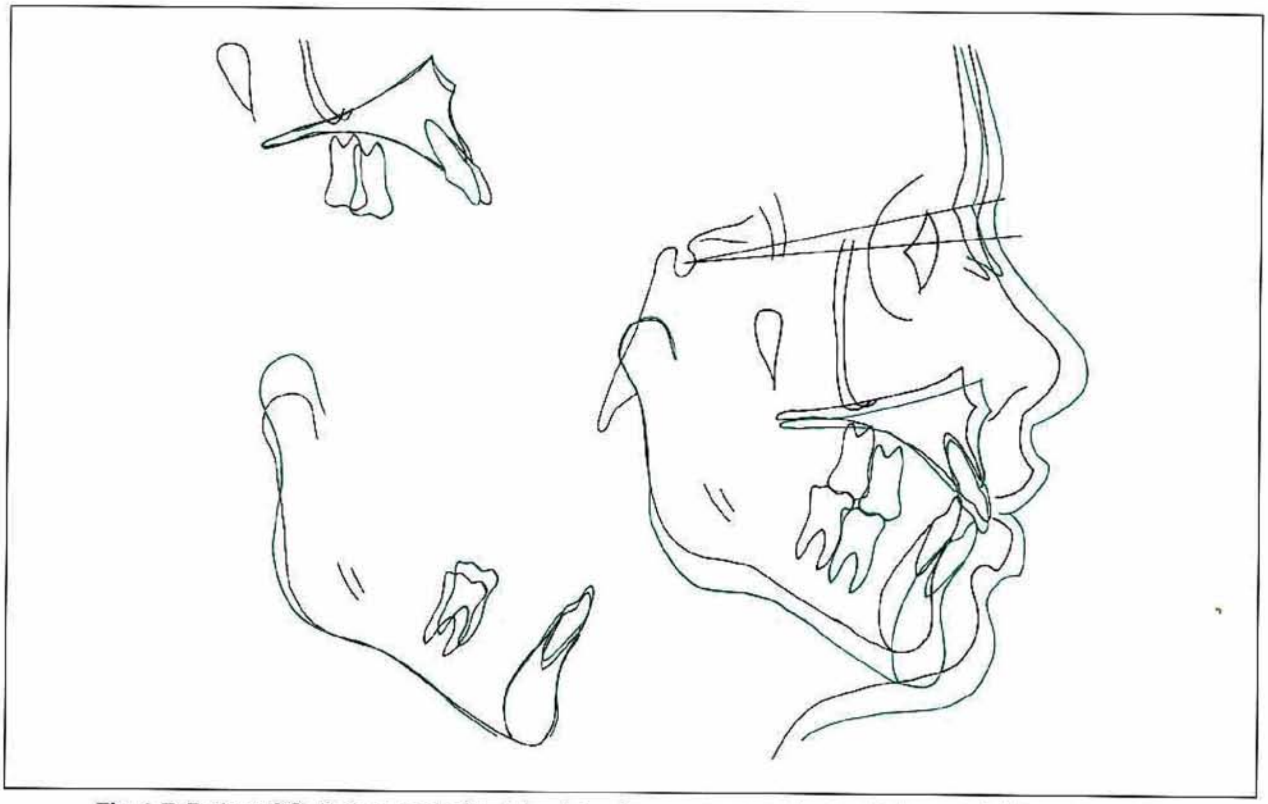
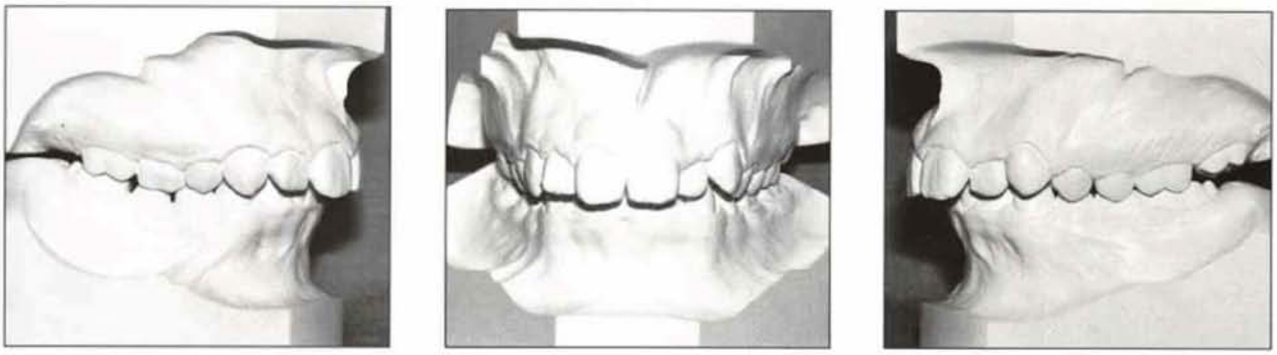


Fig 1-7 Patient GC. Before and after lateral tracings superposed on anterior cranial base, maxilla, and mandible. Treatment goals have been met (see Fig 1-4).

Fig 1-8 Patient GC. Pretreatment facial photos.

Fig 1-9 Patient GC. Posttreatment facial photos. Lip protrusion has been reduced.



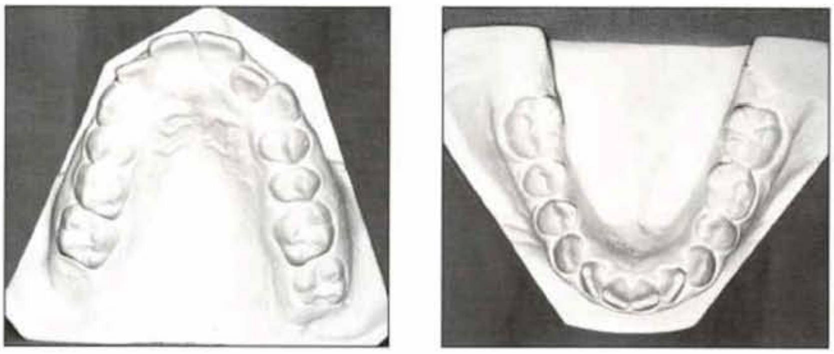
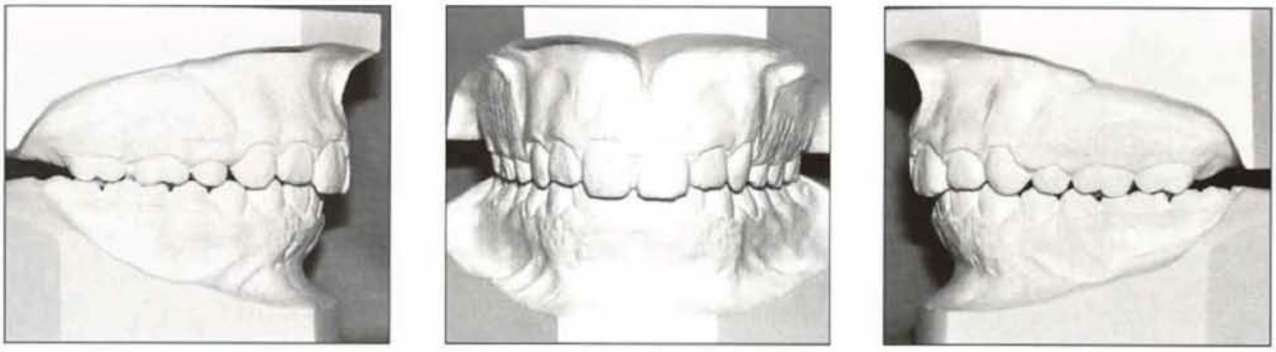


Fig 1-10 Patient GC. Pretreatment dental casts. Class II malocclusion with deep overbite.



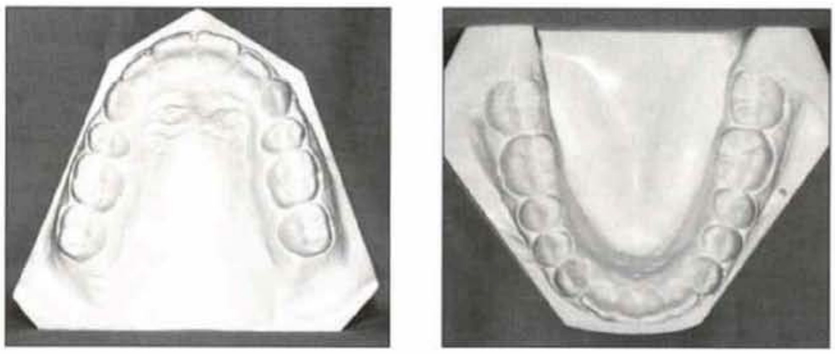


Fig 1-11 Patient GC. Posttreatment dental casts.

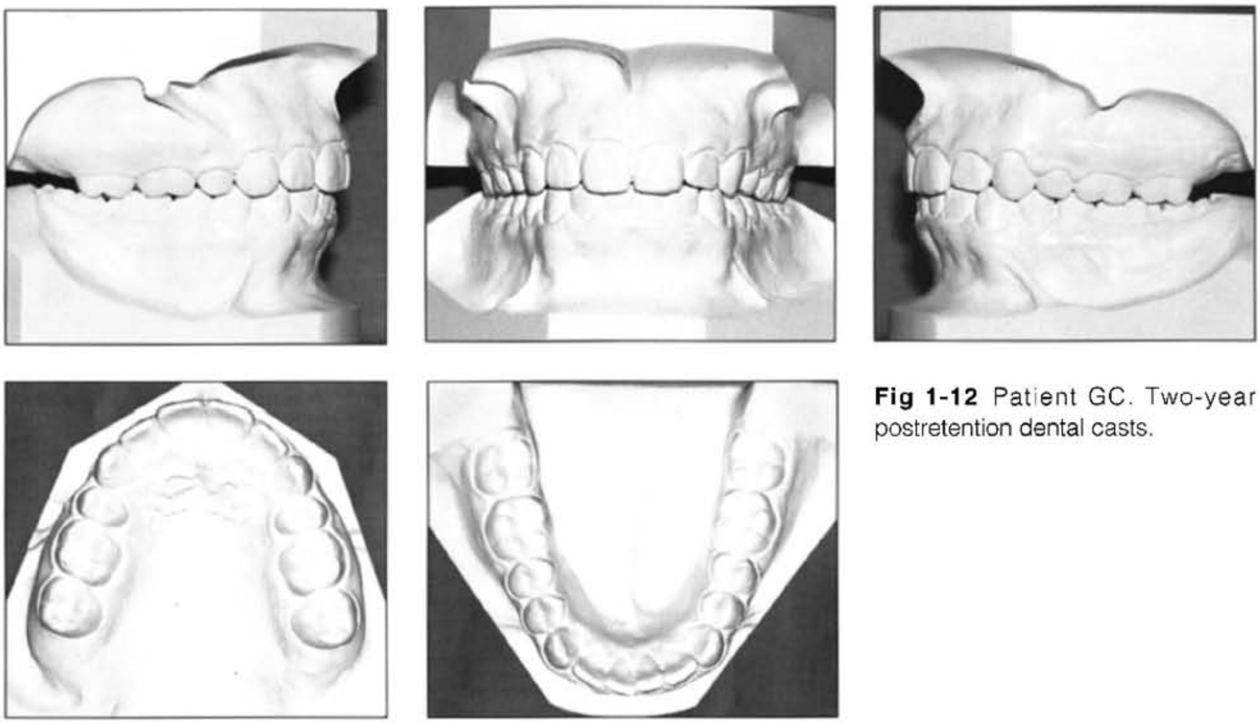


Fig 1-12 Patient GC. Two-year postretention dental casts.

It should be remembered that tracings are visual treatment objectives and not treatment predictions. For example, when Class II elastics are routinely used during orthodontic treatment, the cant of the occlusal plane is steepened. In some patients, especially those who have long lower facial heights, the eruptive effect of the Class II elastics causes the mandible to rotate downward and backward, increasing the already too-long lower facial height. These changes can be illustrated in a prediction tracing and they may, in fact, be very predictable, but only, unfortunately, of undesirable treatment. The tracings described in this text are optimal treatment goals and may or may not be reached completely at the end of treatment.

Routinely unrealistic orthodontic treatment goals suggest that a modification in treatment-planning procedures is needed. This is one of the advantages of carrying out a thorough reanalysis with before- and after-treatment radiographic tracings; one can face the realities involved in reaching the treatment goals.

In the following chapters, a step-by-step decision-making process will consider major treatment goals, the factors that can be used to achieve these goals, the limitations inherent in current therapy, and the process of making three-dimensional tracings.

2

Chapter

Skeletal Changes

The starting place for establishing orthodontic treatment goals is the determination of any skeletal changes that need to be made between the jaws horizontally, vertically, and/or transversely. This is analogous to the denture setup in prosthetic dentistry, which cannot begin until the relationship between the maxilla and the mandible is established. The orthodontic challenge is even greater since one must account not only for a correct centric relation initially, but also for the changes that occur between the jaws over time. Part of this change is no more than the individual growth pattern of the patient, independent of any treatment. However, part of the change could also be related to the mechanotherapy, which could rotate the mandible or potentially produce some orthopedic effect.

Estimating Growth and Its Significance

Typically, the mandible descends downward and forward at a faster rate than the maxilla. This leads to an improvement of the skeletal relationships in a Class II patient and a worsening pattern in the Class III patient.

One of the most important parts of a graduate orthodontic curriculum is the study of the growth and development of the face. It is remarkable that, for many orthodontists, growth is considered only a didactic subject and is not directly applied to treatment planning. There are probably two reasons for this: (1) the large magnitude of the growth changes in comparison to actual tooth movement is not fully appreciated—that is, in some patients, growth can account for more of the changes than tooth movement; and (2) it is widely recognized that there is a broad variation in growth magnitudes and direction, which can be discouraging when making growth estimates or predictions.

In an area of confusion, various viewpoints have emerged. These viewpoints can be characterized according to three groups: optimists, pessimists, and nihilists. Optimists say that all problems involved with orthodontic treatment will be resolved by growth: correction of the Class II malocclusion, undesirable changes in the occlusal planes, temporarily unstable tooth positions, and so forth. Optimists tend to look at growth as the orthodontist's friend. Pessimists, on the other hand, look at growth as the orthodontist's enemy. They say that the Class II is not corrected or the Class III correction failed "because of an undesirable growth pattern." This may or may not be correct, but often the fault lies in an unrealistic treatment plan and its execution. The nihilist does not believe in growth at all: he says, "Let's pretend that growth doesn't really exist, so we

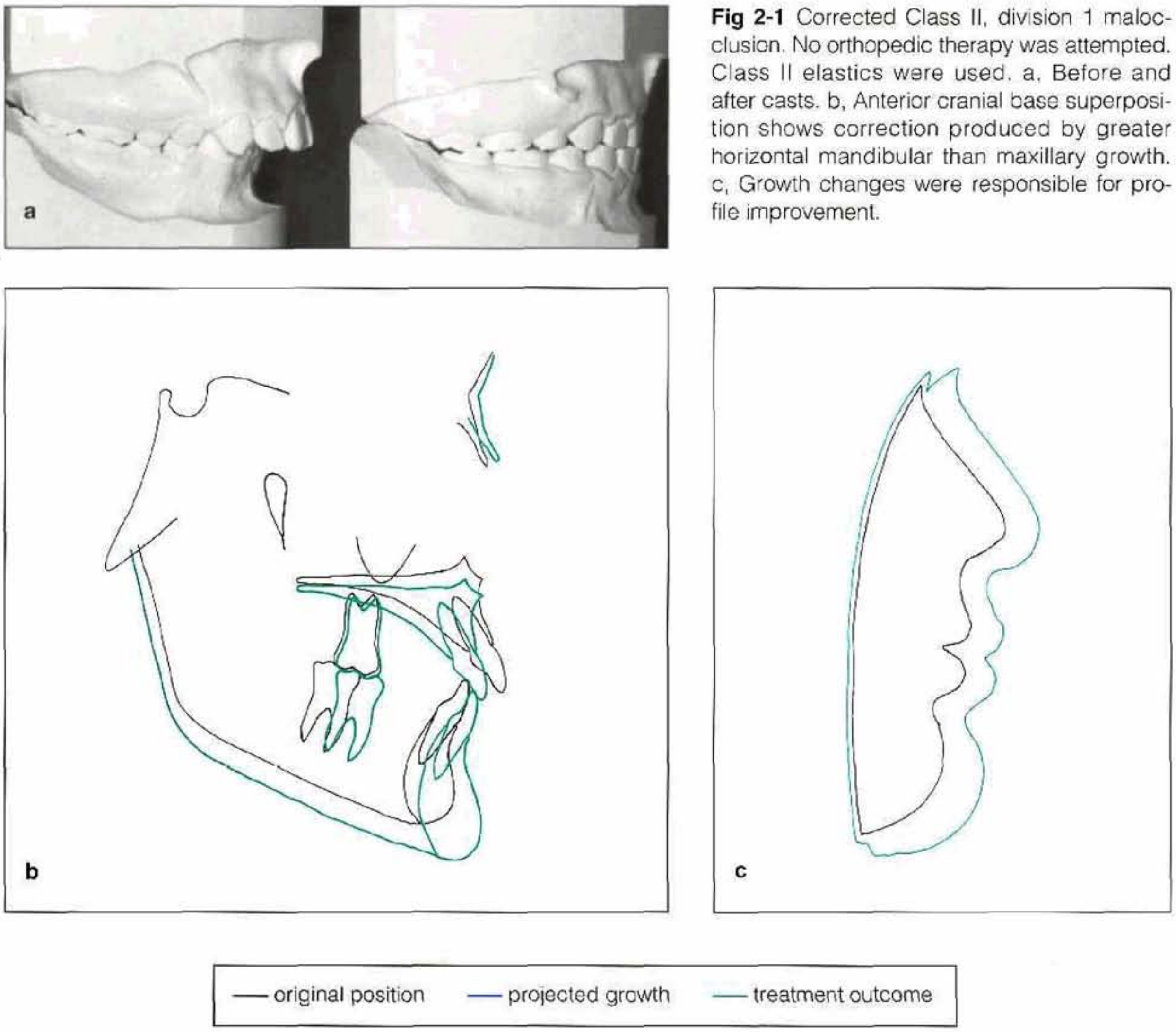


Fig 2-1 Corrected Class II, division 1 malocclusion. No orthopedic therapy was attempted. Class II elastics were used. a, Before and after casts. b, Anterior cranial base superposition shows correction produced by greater horizontal mandibular than maxillary growth. c, Growth changes were responsible for profile improvement.

can do all of our planning from the original position of the teeth alone." Of course, it is always possible to be an optimist on treatment successes and a pessimist on treatment failures.

Because this relationship between the maxilla and the mandible is so important in an orthodontic treatment plan and because growth alters the relationship of the maxilla to the mandible, some growth estimation is necessary in our growing patients. In the Class II patient, independent of any orthopedics, there are important horizontal and vertical denture base changes that occur, ie, changes between points A and B.

Dental casts of a corrected Class II, division 1 malocclusion are shown in Fig 2-1a. One may wonder how the Class II occlusion was corrected. (Treatment included extraction of teeth and some Class II elastics.) The cranial base superposition (Fig 2-1b) demonstrates that most of the change was a differential growth between the maxilla and the mandible. This has also led to a desirable change in the facial profile (Fig 2-1c).

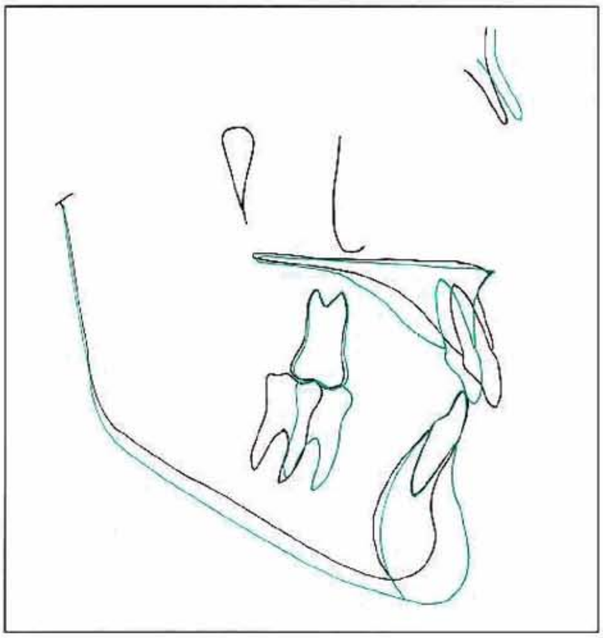


Fig 2-2 Point B moved forward of point A by 6 mm relative to the occlusal plane. Normal growth, not tooth movement, accounts for the correction of the Class II malocclusion. Cranial base superposition.

Figure 2-2 shows another patient with Class II malocclusion in whom differential growth has led to a correction of the Class II relationship. If the horizontal distance between Pg and point A is measured along the occlusal plane, 6 mm of growth-related change is seen.

In Fig 2-3, the patient exhibits a Class II malocclusion with a deep overbite. She was treated with occipital headgear, which was designed to restrain the upper teeth and jaw as the mandible grew forward. A growth prediction using averages showed that the mandibular growth alone could correct both the Class II malocclusion and the overbite, thus minimizing tooth movement (Fig 2-3a). Superposed headfilm tracings show that the growth increments and direction approximate the prediction (Fig 2-3b). In addition, molars have translated distally. The forward displacement of the maxilla is slightly less than average, which might represent a small orthopedic effect. The upper molars after treatment are not tipped distally since the headgear force was directed through their centers of resistance (Fig 2-3c).

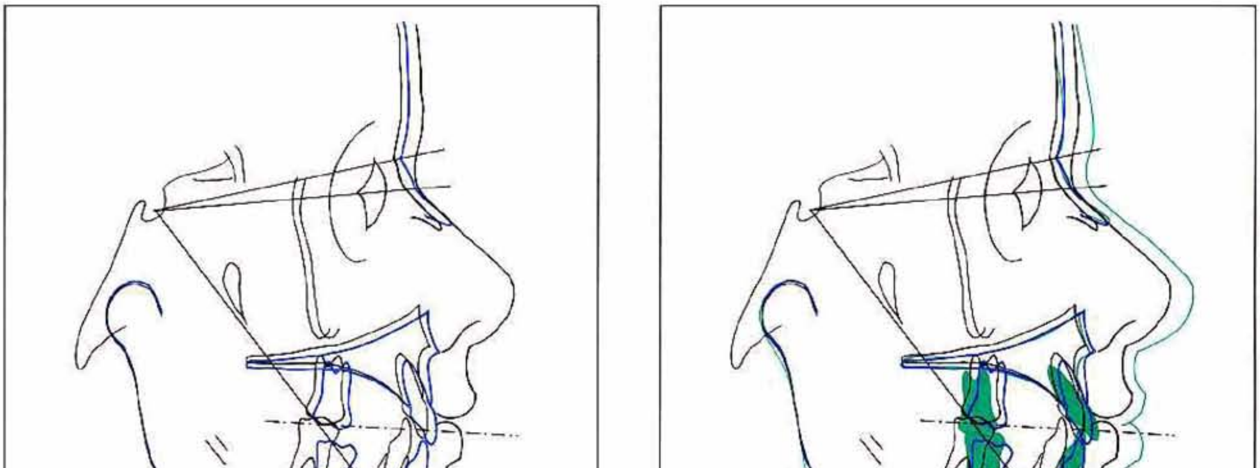
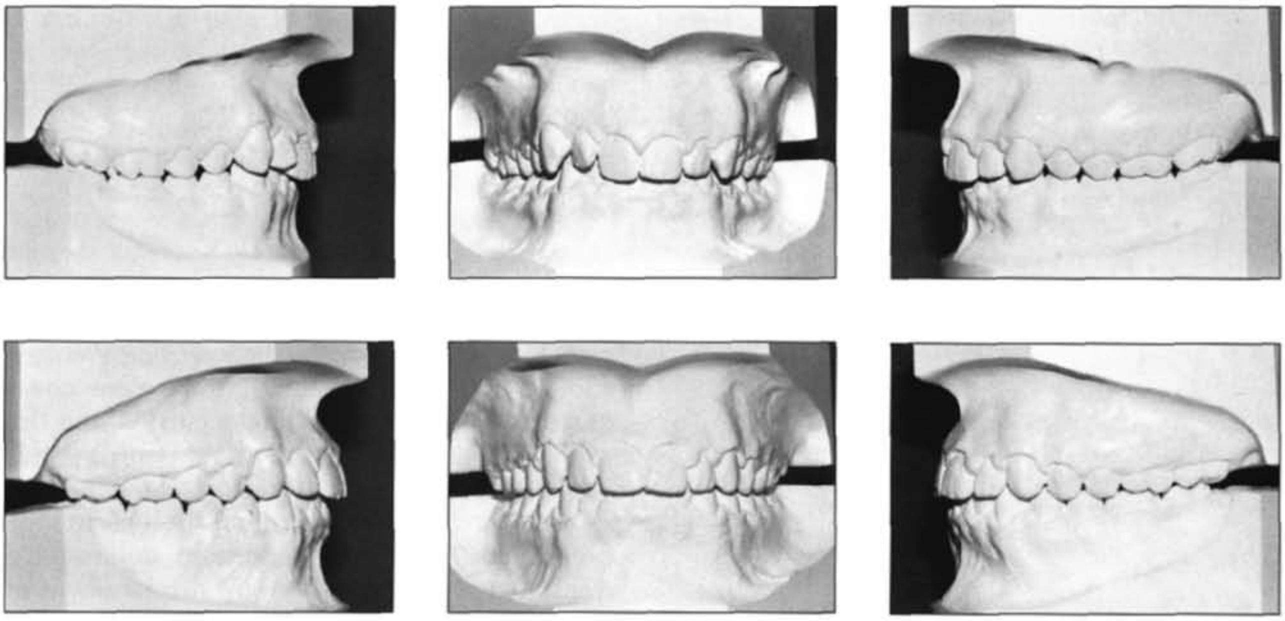


Fig 2-3 Average growth increments corrected both horizontal and vertical deep overbite in a Class II patient. a, Average growth prediction with teeth in original position. Note correction of both Class II malocclusion and overbite. b, Superposed before and after tracings show that growth approximates predicted averages. Distal movement of the molars also is evident. c, Dental casts before and after treatment. Little tooth movement was required to correct the malocclusion.



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The greater descent of the mandible over the maxilla has important ramifications for vertical correction, in patients both with deep overbite and with open bite. Figure 2-4 shows two growth predictions: in Fig 2-4a average growth is predicted, and in Fig 2-4b growth changes are minimal. Both patients have Class II malocclusions.

In Fig 2-4a, note that growth, as expected, has improved the horizontal relationship, reducing the overjet while reducing the overbite as well. In Fig 2-4b, little change is seen, and either tooth movement or mandibular rotation would be required for correction of the deep overbite.

The details of a growth prediction are given in the appendix; in the growth-prediction procedure, the positions of the teeth are not changed during growth (Fig 1-4). Hence, they can serve as markers of the growth changes that occur vertically and horizontally. Because the maxillary and mandibular molars remain in their original positions, as the mandible descends in the growth prediction, a space is created between the teeth. This space is referred to as the *intermaxillary growth space*. It is important because it gives the clinician an opportunity either for upward and forward rotation of the mandible or for selectively erupting the teeth to alter the level and/or cant of the occlusal plane. Changes in the vertical dimension affect not only the occlusion and the face but also jaw function: that is, ease of lip closure, swallowing patterns, and the overall stability of the treatment result.

Although the growth prediction is based on average growth increments, these increments are based on a developmental or facial age. Increments based on a facial age rather than on a chronological age are more predictive since they tend to be larger. Growth averages based on chronological age can be misleading because they imply to the clinician that growth increments are less than the increments normally present during peak growth velocity. If a sample of different "ages" was averaged only by chronological age, the resulting increments at peak velocity would be small since peak velocities occur at different ages among the early, average, and late maturers. A developmental (facial) age is a better predictor because the comparison is made among individuals who are at the same stage of development. One must be careful in using growth estimates even from corrected values based on facial age since, at any developmental age, there can be considerable variation in growth increments. The larger mandibular growth

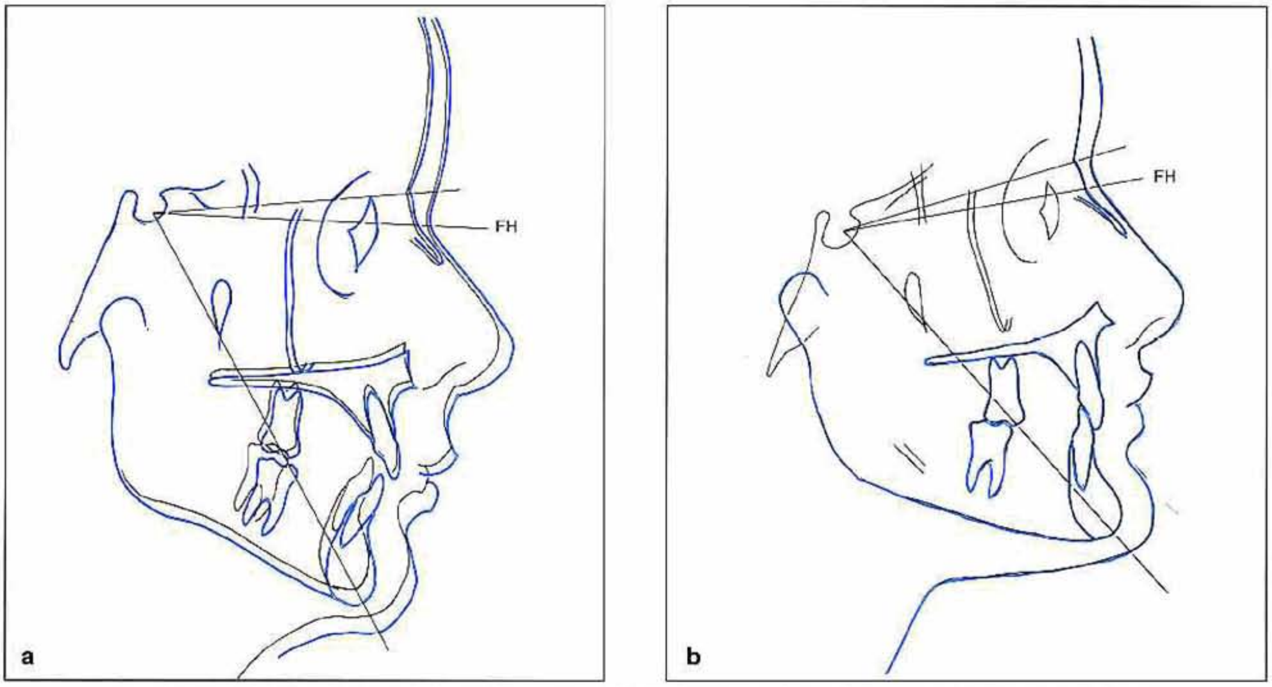


Fig 2-4 Growth influences treatment goals and mechanics. Shown here are untreated patients with teeth traced in original positions in the maxilla and mandible. The 2-year growth approximation is shown in blue. a, Deep overbite can be corrected by extrusion of posterior teeth into the intermaxillary growth space. b, Small growth increments require incisor intrusion if stability cannot be achieved by increasing the vertical dimension.

— original position — projected growth

increments (Ar–Pg) using facial age are shown in Fig 2-5.

For example, in the male at peak growth velocity at 14½ years of age, the average mandibular growth increment per year (Ar-Pg) is 4.7 mm, with a standard deviation of 1.2 mm. Although most individuals cluster around the mean, at three standard deviations, one could expect 3.6 mm more or less than the average (Fig 2-6).

It is this variation that confounds the clinician and explains treatment successes and failures, assuming that there is patient compliance with headgear use and/or functional appliance therapy.

One could then ask why, if there is so much variation in growth increments, should one even attempt a growth prediction? A reasonable answer is that, for those patients in whom growth is important, such as Class II and Class III patients, or for those patients with a problem in the vertical dimension, an inaccurate growth prediction is better than no prediction at all. An average growth prediction gives one the opportunity to make reasonable decisions about what might be considered a realistic course of treatment.

The increments of growth vary considerably depending on the level of maturation. Note the incremental variation of the dimension Ar-Pg in Fig 2-7. Looking at the growth curve for males, for example, the potential for Class II correction by growth is greater at the time of peak velocity (14.6 years) than it is at the point of inflection on the growth curve, 11.6 years of age. One very important component of the patient workup is to establish the level of maturation of the face. Although hand-wrist radiographs have been used to determine maturation level, their usefulness is limited to those patients in whom a considerable difference exists between chronological age and

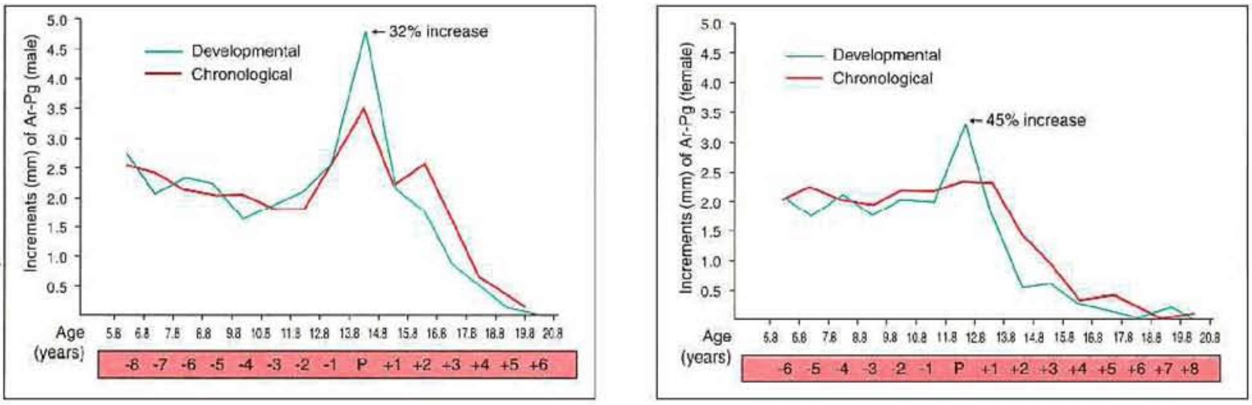


Fig 2-5 Compare mandibular growth increment curves (Ar–Pg) using chronological and developmental age. Averaging of early and late maturers tends to flatten the chronological age curve. The developmental age curve more closely resembles the individual's growth curve.

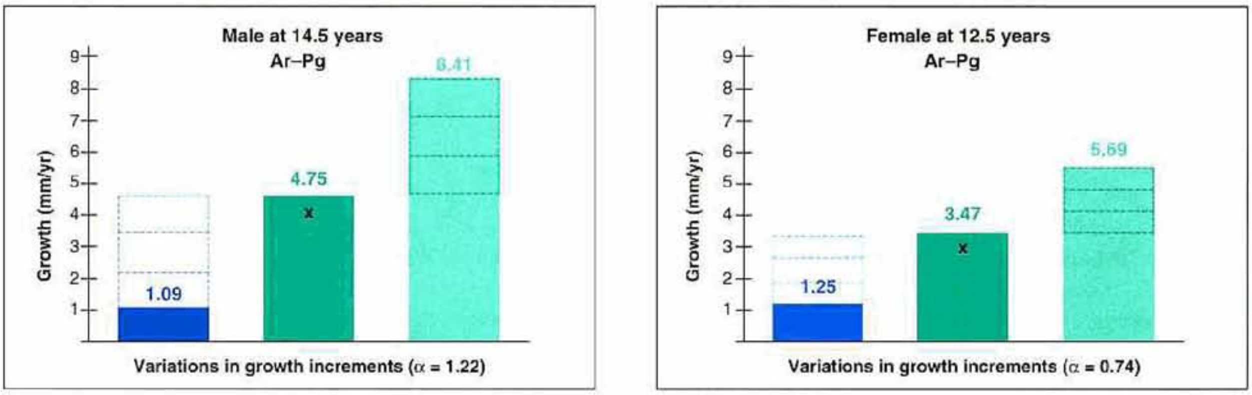


Fig 2-6 Variations in growth increments of the mandible at peak velocity. Large variation leads to unsatisfactory prediction and treatment.

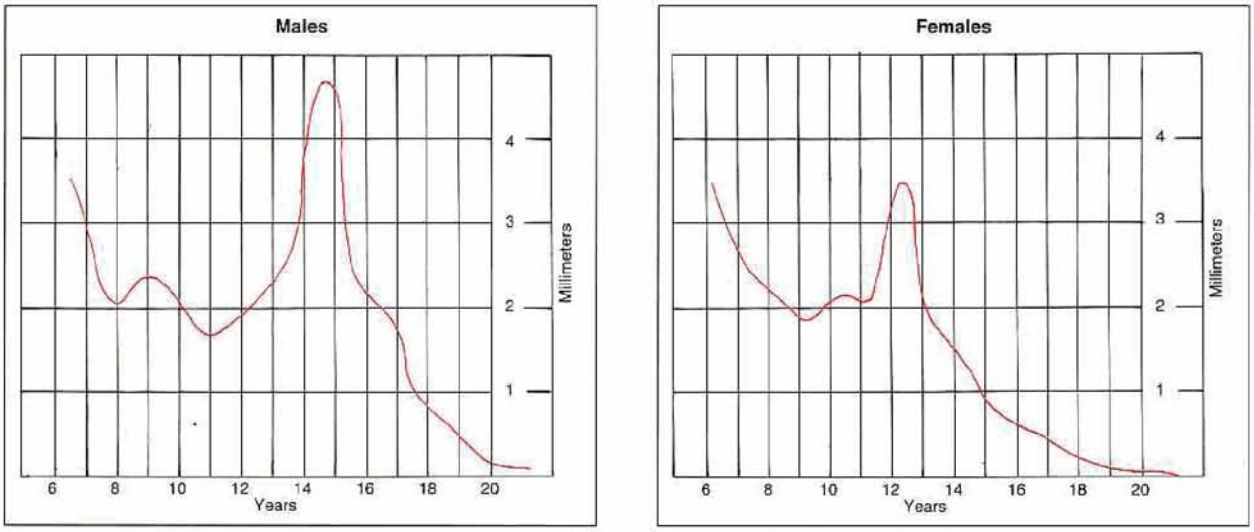


Fig 2-7 Incremental growth curve of mandibular length (Ar–Pg) based on facial age.

developmental age. Better and more practical clinical maturation guides include height curves, longitudinal headfilms when available, an evaluation of the sexual development of the patient, and an examination of a patient's familial patterns.

Perhaps the most important aspect of any growth prediction is the estimate of the developmental or facial age of the patient. An early-maturing boy at 9 years of age can be equivalent to a 14.6-year-old boy going through his peak growth velocity. Furthermore, in an early maturer, the increments of growth at the 9-year peak velocity could actually be greater than those in the average maturer.

Superposed on the normal growth of the patient are the skeletal changes produced during treatment. In certain instances these skeletal changes may be significant but may pale in contrast to the magnitude of the growth that occurs without treatment.

In the transverse plane, normal growth influences the relative widths of the maxilla and the mandible. Because the mandible displaces forward more than the maxilla, the mandibular transverse base becomes relatively wide in relation to the maxillary base. This can lead to crossbites, particularly in patients who exhibit some transverse discrepancy initially.

Thus, nonorthopedic growth is highly significant for the prognosis and for the ease and timing of treatment. One cannot plan specific tooth movement until the best estimate of the maxillomandibular relationship at the end of the treatment period is established. Can one rely on the average growth increments to predict the facial growth for an individual orthodontic patient? Much variation can exist, so the orthodontist should proceed with caution when using a growth prediction. On the other hand, ignoring growth can lead to major errors in planning treatment.

Rotation of the Mandible

Increases or decreases in vertical dimension can be produced during treatment by extrusion, intrusion, or relative intrusion, with growth, of the posterior teeth. These changes occur as the mandible is rotated either open or closed. Because these vertical changes are small, the mandible rotates on its hinge axis. With rotation, two components of the displacement of analogous points, horizontal and vertical, must be considered because of their clinical significance. Thus, it is nearly impossible to alter the vertical dimension without influencing the horizontal position of the teeth and the chin.

To understand and plan mandibular rotation, the choice of a reference plane is important. If one wants to relate points on the mandible to the face, a plane such as the Frankfort horizontal can be chosen. In Fig 2-8, the mandibles of two patients—one with a steep mandibular plane (patient A) and another with a flat mandibular plane (patient B)—are both rotated open 5 degrees (Table 2-1).

To evaluate chin position for facial esthetics, the Frankfort horizontal is selected as the reference plane. In patient A, Pg moves down 4.0 mm and back 8.5 mm, the ratio of the vertical to horizontal change being 0.5 (Table 2-1). The vertical to horizontal (v/h) ratio of Pg to the occlusal plane is greater at 0.9. In patient B, the occlusal plane is nearly parallel to the Frankfort horizontal (Fig 2-8), and therefore the v/h comparisons between the two reference planes are identical. When calculating the effects of rotation on the dentition, the proper plane of reference should be the treatment plane of occlusion.

Table 2-1 Vertical and Horizontal Changes (mm) with 5 Degrees of Mandibular Opening

	To FH			To OP		
	Vertical	Horizontal	V/H	Vertical	Horizontal	V/H
Patient A						
Lower incisor	6.0	6.0	1.0	7.0	4.0	1.8
Pogonion	4.0	8.5	0.5	6.0	7.0	0.9
Lower first molar	3.0	5.0	0.6	5.0	4.0	1.3
Patient B						
Lower incisor	7.0	4.0	1.8	7.0	4.0	1.8
Pogonion	7.0	5.5	1.3	7.0	5.5	1.3
Lower first molar	6.0	3.5	1.7	6.0	3.5	1.7

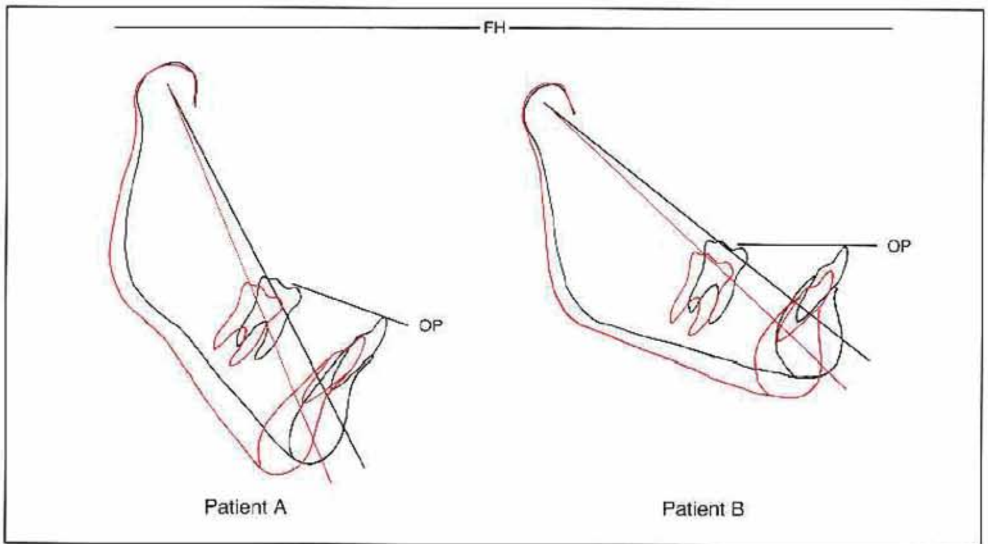


Fig 2-8 Rotating a mandible open around an arbitrary condylar hinge axis produces horizontal and vertical changes in Pg (5 degrees of opening). (OP = occlusal plane; FH = Frankfort horizontal).

— original position — treatment objective

As can be seen from the tracings in Fig 2-8 and the data in Table 2-1, the absolute magnitude of the displacement and the v/h ratio vary with the landmark selected. For example, in patient A (Fig 2-8), Pg moves back 7.0 mm but the lower molar moves only 4.0 mm to the occlusal plane. These changes, given for vertical and horizontal displacements and for the v/h ratio, reflect only the simple geometry of rotation; nevertheless, these principles may not be ignored by the clinician.

Two patients are shown in Fig 2-9: patient A has a large FH–Ar–Pg angle (57 degrees) and patient B has a smaller FH–Ar–Pg angle (33 degrees). Although the opening angle is the same (5 degrees) for both patients, the horizontal displacement is greater for patient A. The v/h ratio of patient A is 0.4; ie, for every 0.4 mm of vertical opening in patient A, 1.0 mm of horizontal displacement occurs. For patient B, the v/h ratio is 1.2; ie, for every 1.2 mm of opening, 1.0 mm of horizontal displacement occurs.

Thus it can be seen that as the angle between a horizontal plane (eg, Frankfort horizontal) and the line Ar-Pg increases, a hinging-open rotation

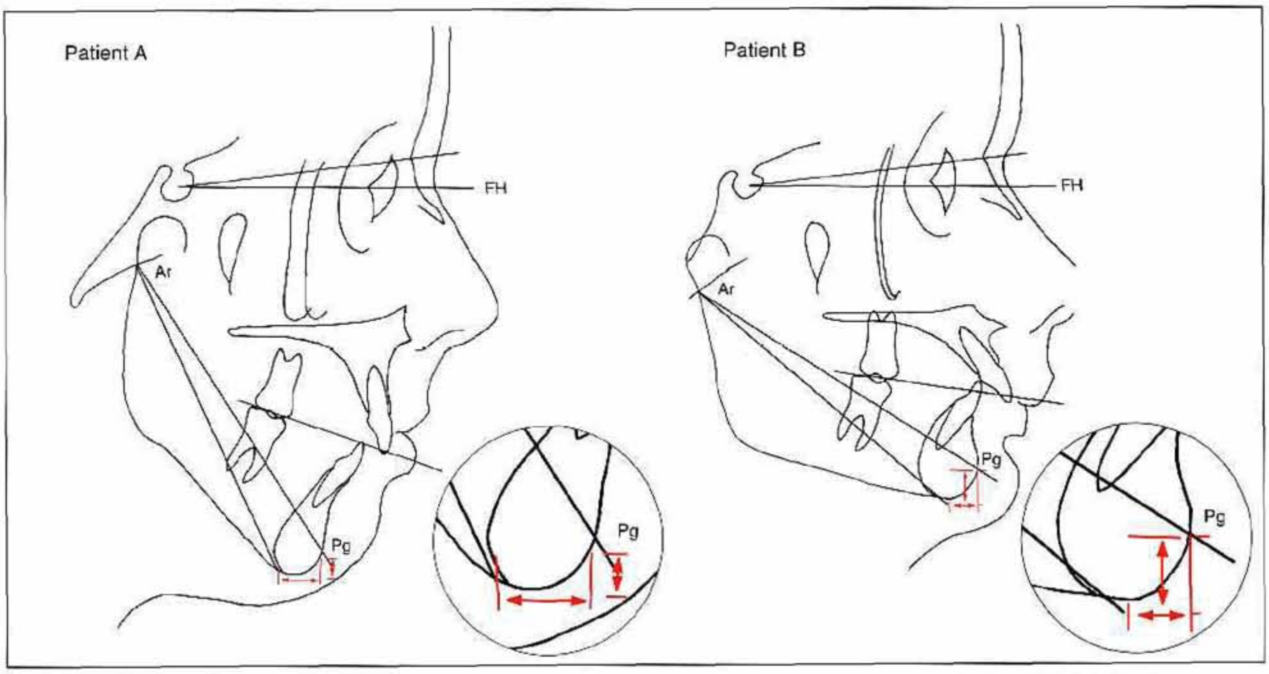


Fig 2-9 As the FH–Ar–Pg angle increases by 5 degrees, a greater horizontal to vertical effect at Pg is produced in patient A as compared to patient B.

has a greater horizontal than vertical effect. The decision to rotate a mandible open or closed, then, should be determined by its effect on the vertical dimension, the facial convexity, and the potential occlusal plane divergence, and not on an orthodontic symptom such as deep overbite.

Figure 2-10 shows a patient with a deep overbite, a convex face, and an increased lower facial height. It would be improper to rotate the mandible open to correct the deep overbite as it would increase the facial convexity.

Some have used skeletal dimensions—for example, the dimension from anterior nasal spine (ANS) to Me—to determine the desired vertical height of the face. This may be misleading since ANS varies considerably vertically and is hidden by soft tissue structures. In addition to the skeleton, soft tissue factors must be considered when determining the desired vertical height of the face. One reliable soft tissue relationship is the ratio between G' and Sn and Sn to Me'. In most age groups, this ratio is approximately 1:1. Another more significant soft tissue factor is the interlabial gap. Typically, with lips relaxed, there is about 2 mm between the upper and lower lips. Patients with larger-than-average interlabial gaps

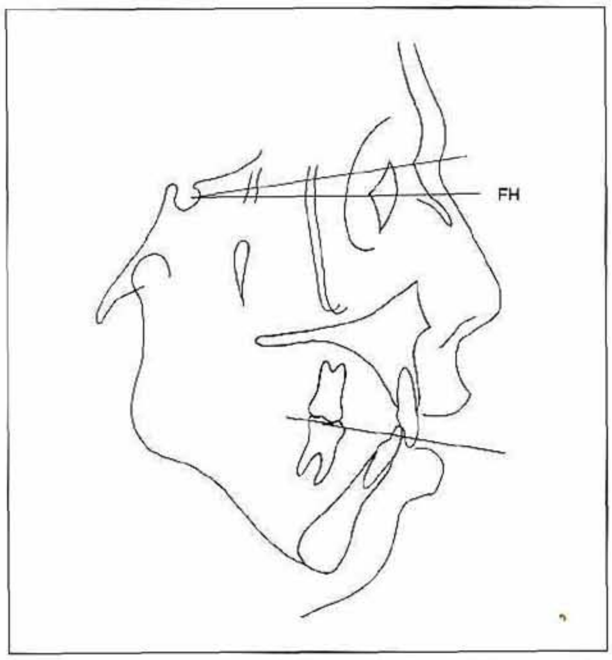


Fig 2-10 "Opening the bite" is not indicated to correct a deep overbite in patients with excessive vertical dimension.

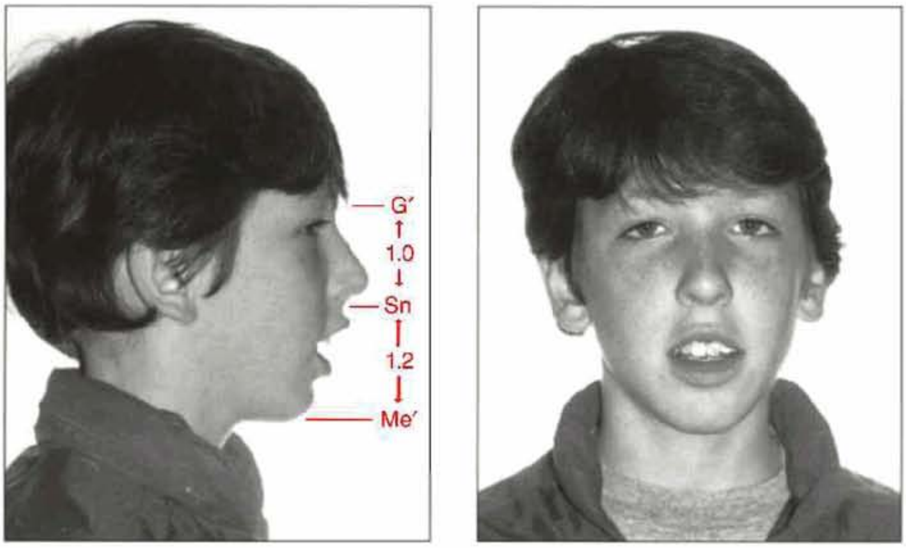


Fig 2-11 Patient with an excessive interlabial gap. Interlabial gap along with proportions (G′–Sn/Sn–Me′) can be used to establish vertical dimension from an esthetic and functional viewpoint.

may require a reduction orthodontically or surgically in the facial vertical dimension (Fig 2-11).

Figure 2-12 shows a patient with a large anterior open bite and two separate occlusal planes. This extreme condition requires orthognathic surgery to eliminate in part the divergence between the maxillary and mandibular occlusal planes. At the end of treatment, there must be only one occlusal plane; ie, the maxillary and mandibular must be parallel to each other and separated by 2 mm, the amount of the normal overbite. This extreme condition is shown as a reminder that, even in nonsurgical cases, there can be two or more occlusal planes, and rotating the mandible open to correct the deep overbite can increase the divergence and produce an open bite.

A Class III malocclusion patient with a +1.0 mm mesial shift is shown in Fig 2-13. Correction was achieved in part by rotation of the mandible downward and backward. This is indicated only if there is excessive freeway space, a normal interlabial gap, or redundant lip length and a small vertical dimension. "Hinging open" of the mandible in Class III patients may not be stable, so discretion in increasing the vertical dimension is advised. The patient in Fig 2-13 was treated with Class III elastics, which flared the maxillary incisors and brought the maxillary molars forward. The excessive lip length seen in the tracing further supports the suitability of the mandibular rotation.

The mechanotherapy required for rotation of the mandible upward and forward (hinging closed) is much more difficult. With growth, the intermaxillary growth space could be used, at least in part, to produce the effect of forward rotation. In some situations it is possible to produce some actual intrusion of upper posterior teeth. In Fig 2-14, the closure of an open bite by the use of a chin cap is seen.

This patient exhibited a steep mandibular plane with an excessive vertical dimension and a large interlabial gap. Force from a chin cup was directed vertically through the dental arches. The headfilm tracing demonstrates that the open bite was corrected mainly by holding the upper molars vertically with some intrusion seen in the lower molars, resulting in upward and forward mandibular rotation (Fig 2-14c). Little of the correction was produced by incisor eruption. At the beginning of treatment, both upper and lower arches were relatively flat. The open bite was associated with a maxillomandibular divergence, which produced a lack of parallelism between the maxillary and mandibular occlusal planes. By rotating the mandible closed, parallelism was restored and the open bite was corrected.

Chin cups have been used for Class III correction. Design of a chin cup for Class III patients directs the force posteriorly through the condyles. To rotate the mandible upward, the line

Fig 2-12 Patient KB. Anterior open bite. Divergence of maxillary and mandibular occlusal planes. Maxillary and mandibular arches are relatively level. Rotating the mandible open would increase occlusal plane divergence.

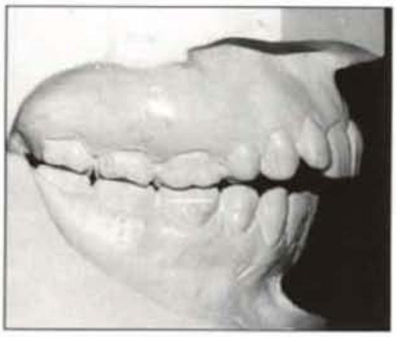
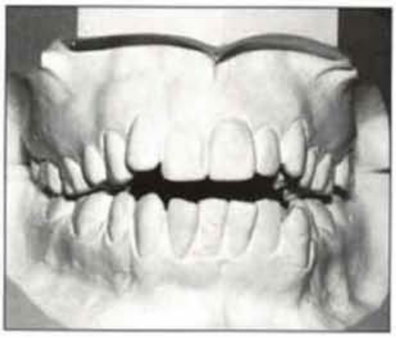
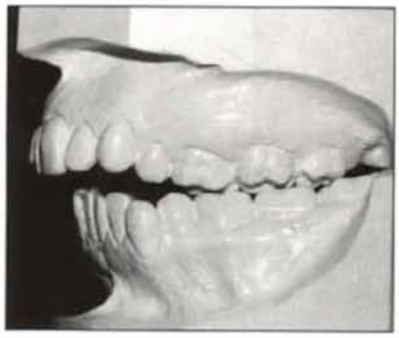




Fig 2-12a Study casts.

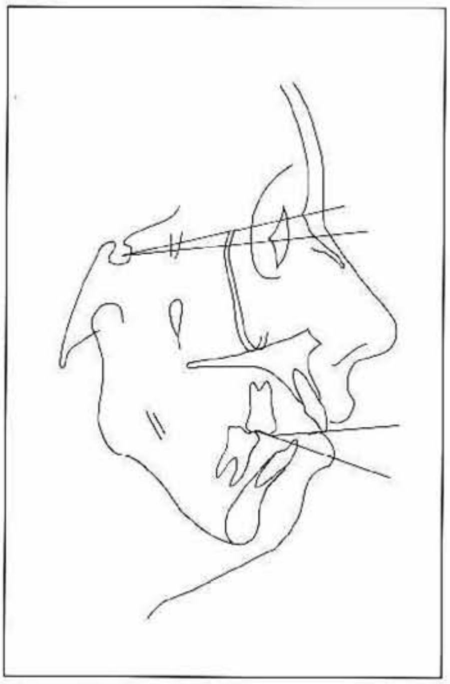



Fig 2-12b Headfilm tracing of open bite.

Fig 2-12c Profile view.

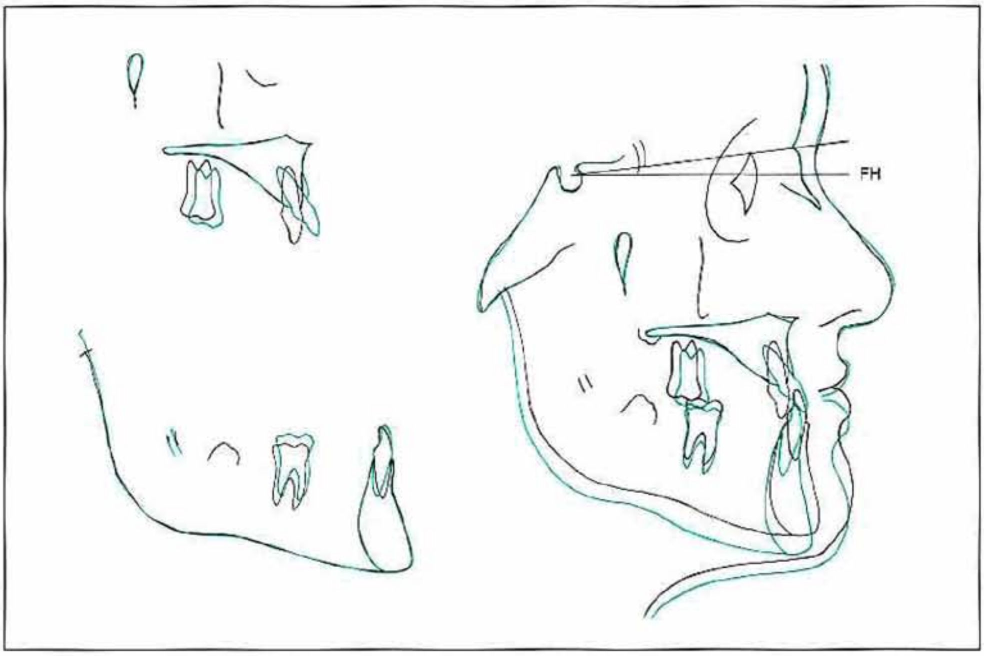
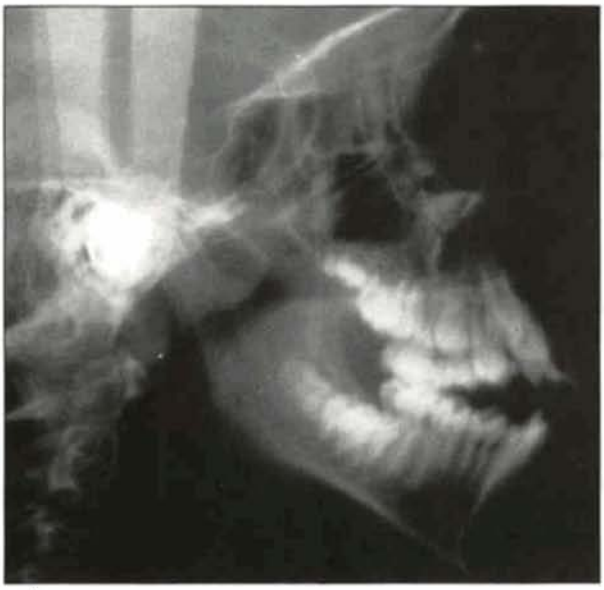


Fig 2-13 Patient MF. Skeletal improvement of a Class III malocclusion by downward and backward rotation of the mandible and by protraction of the maxillary arch. Black, original tracings. Green, treatment result 2 years later.

Fig 2-14 Patient DP. Closure of open bite by use of chin cup. The mandible was rotated upward and forward by holding the molars with slight intrusion of the lower molars. (Courtesy of Dr L. Pearson.) a, Pretreatment radiograph. b, Posttreatment radiograph. c, Pretreatment (black) and posttreatment (green) tracings superposed. d, Before treatment. e, After treatment.



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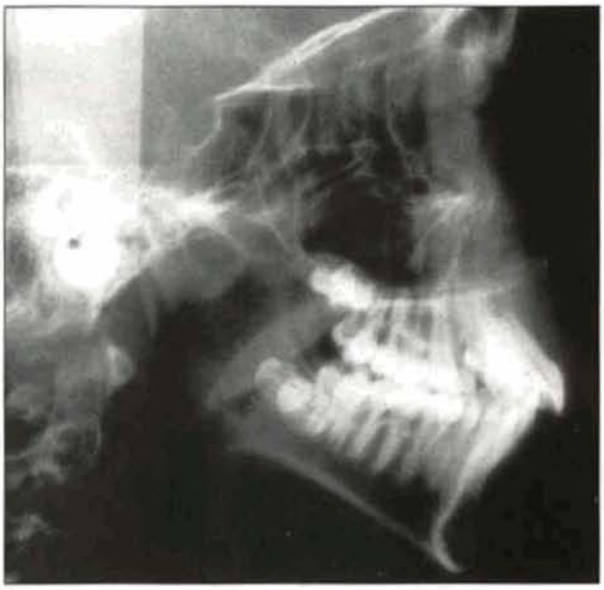

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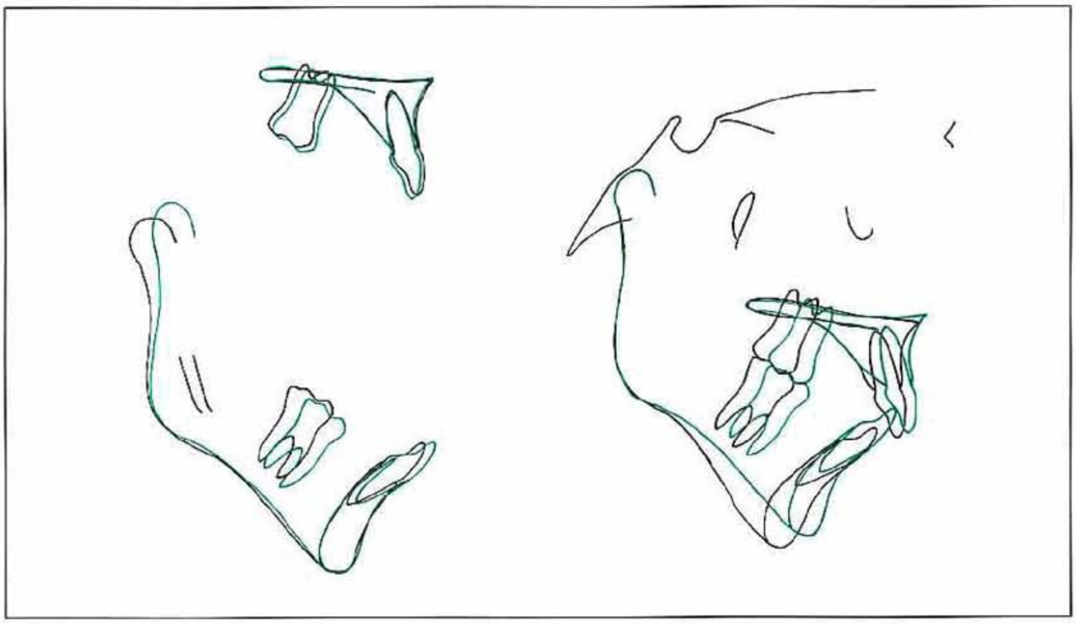

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— original position — treatment outcome

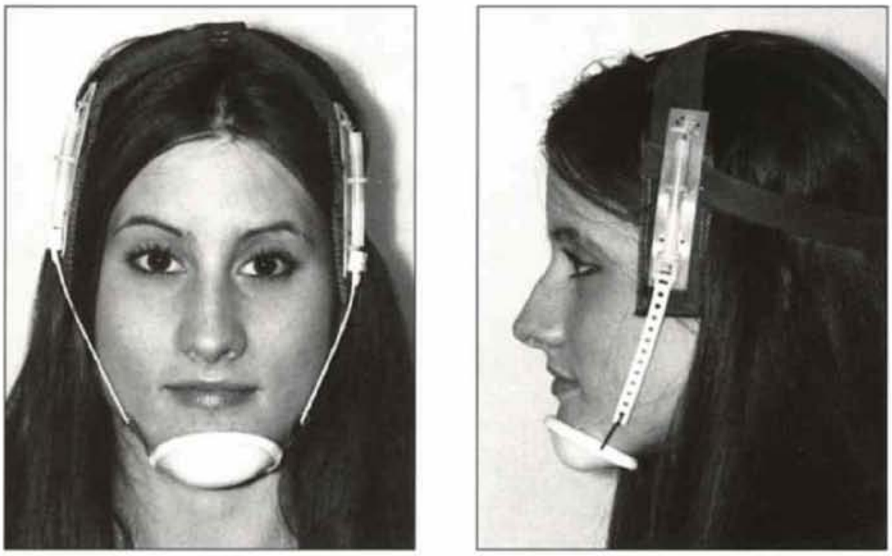


Fig 2-15 Chin cup design. To rotate the mandible closed, force is directed through the posterior teeth, not through the condyle.

of force should be through the centroid of the roots of the lower arch. A headgear of this design is seen in Fig 2-15.

Facial Orthopedics

Edward Angle and his followers believed that broad skeletal changes could be produced by orthodontic treatment. Anything was possible, they believed, because malocclusions developed from "environmental factors." Early studies by Brodie and others in the late 1940s and 1950s suggested that the skeletal pattern could not be altered significantly. The concept of "the stability of pattern" was developed, reducing orthodontics primarily to dentoalveolar changes. Today, the consensus is that some orthopedic changes can occur but that they are limited in magnitude and, when they do occur, stability may be a problem.

Rotation of the mandible, in one sense, could be considered orthopedic. Stability of rotation is not always assured. In some instances of deep overbite, for example, if the mandible is rotated open, there is a tendency for it to return to its original position, leading to a return of the deep overbite. The effect of a closed rotation of the mandible in the growing child also might be unstable with age.

One might ask, can the position of the maxilla be altered orthopedically, with appliances such as a typical headgear or a protraction headgear? With good headgear compliance, it might be possible to retard the growth of the maxilla by as much as 1.5 mm; similar numbers have been suggested for the use of a protraction headgear. Even with excellent cooperation, the amount of change is relatively small and, rarely, more than 1 to 2 mm. Treatment plans calling for the orthopedic movement of the maxilla forward or backward by 5 mm are unreasonable, although it is within normal variation to find a maxilla descending more forward or backward than average. Following headgear therapy, there can be relapse of the small orthopedic changes that have occurred.

What about mandibular growth? Can orthodontic appliances such as activators and other functional appliances enhance the growth of the mandible? The most dramatic increase in mandibular growth has been observed with the Herbst appliance and others like it. Not only does the length of the mandible increase, but the mandible is rotated upward and forward, which

maximizes a favorable point A to point B correction in Class II patients. However, even these changes may be lost over time. How much additional mandibular growth can one expect when using a Herbst type of appliance? Again, studies have shown that one might expect approximately 1.75 mm more than average growth. Hence, even with excellent patient compliance, one should not expect too much from functional appliances; in fact, some studies have shown similar amounts of mandibular growth using Class II elastics or headgears.

It has already been mentioned that, in growing patients, it is important to estimate the amount of growth that could improve the horizontal point A–point B discrepancy during treatment. It is possible, then, to superpose on this normal growth some *small* increments of orthopedic change. The emphasis here must be on small, ie, 1 to 2 mm or so at most. Growth could still account for a major part of the Class II correction, but this growth is just the normal growth that would have occurred independent of orthodontic treatment.

In the treatment planning of a surgical patient, one must carefully decide where to place the maxilla and mandible horizontally, vertically, and transversely. Unfortunately, there are no nonsurgical methods to significantly alter the growth of the maxilla and the mandible. In examples of maxillary protrusion, headgear alone will not solve the problem. In mandibular retrusion, appliances will not radically "grow the mandible." In many successful Class II patients treated by nonextraction methods, the correction is by non-orthopedic mandibular growth, which may be greater than normal (ie, more than one standard deviation greater than the mean).

Transverse Changes

It is now well documented that, with techniques such as rapid maxillary expansion, it is possible to increase the maxillary width. As in other forms of orthopedic therapy, the relapse potential may be high; nevertheless, some permanent increase can be achieved.

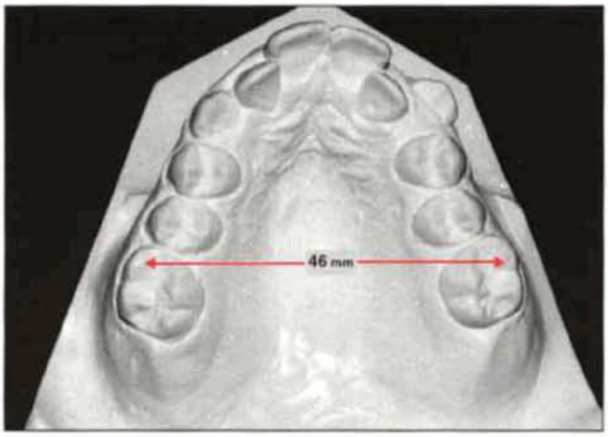
There are a number of indications for increasing maxillary width, the most obvious being a skeletal crossbite. If skeletal crossbites are corrected dentally, ie, by the tipping of the involved teeth, unfavorable axial inclinations of the buccal segments result in an increase in the curve of Monson. Other indications for maxillary expansion that are equally important but not so obvious are: (1) a narrow maxilla with a narrow palatal vault, which can lead to either a low tongue posture or a forward tongue posture. Widening the maxilla can eliminate an etiologic factor in an anterior open bite; (2) an accentuated curve of Monson without the presence of a crossbite (ie, the upper molars tipped buccally and the lower molars inclined lingually). It is not possible to correct these axial inclinations by dental movement alone, since root movement would position the roots either through the buccal plate of the maxilla or through the lingual plate of the mandible.

The last example of an accentuated curve of Monson without the presence of a crossbite is a true skeletal crossbite with dental compensation. The treatment of choice would be first to upright the axial inclinations of the buccal teeth by lingual tipping and then to expand the buccal segments with a maxillary expansion appliance or a surgical procedure. The upper dental cast of a patient treated with this approach is shown in Fig 2-16a. The upper posterior teeth were first tipped lingually with a lingual arch to correct the axial inclinations (Fig 2-16b).

The after-expansion intermolar width shows 17.0 mm of expansion from the uprighted molars (Fig 2-16c); the crossbite has been corrected and the buccolingual axial inclinations have been made normal. The deband upper cast shows the same intermolar width of 56.0 mm (Fig 2-16d). The treatment result remains fairly stable 9.5 years later, with an intermolar width of 55.0 mm (Fig 2-16e).

Figure 2-17 shows a patient with a skeletal crossbite. The upper molars are buccally inclined and the lower molars are lingually inclined. Uprighting these teeth around a center or rotation midway on the root would accentuate the crossbite. In Fig 2-18, there is no crossbite but a skeletal discrepancy in width; compensations in the axial inclinations of the upper and lower molars have, however, masked the discrepancy. Both of

Fig 2-16 Skeletal expansion of the maxilla. (Courtesy of Dr J. Lavin.) Upper molars were tipped lingually before expansion. a, Before (intermolar width, 46 mm). b, After lingual uprighting (intermolar width, 39 mm). c, After rapid palatal expansion (intermolar width, 56 mm). d, After treatment (intermolar width, 56 mm). e, 9.5 years postretention (intermolar width, 55 mm).



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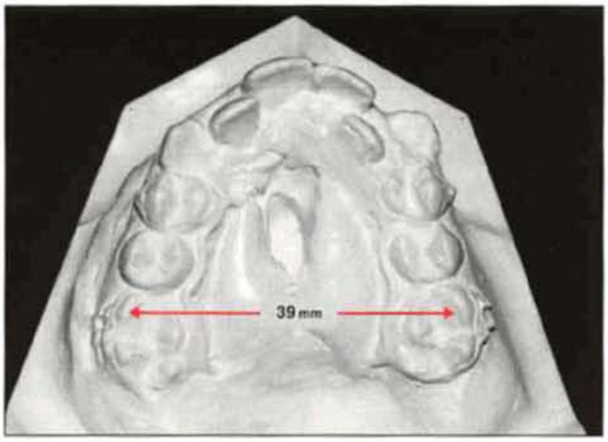

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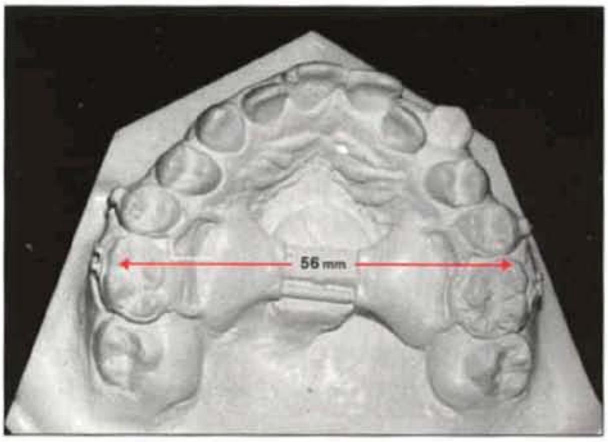

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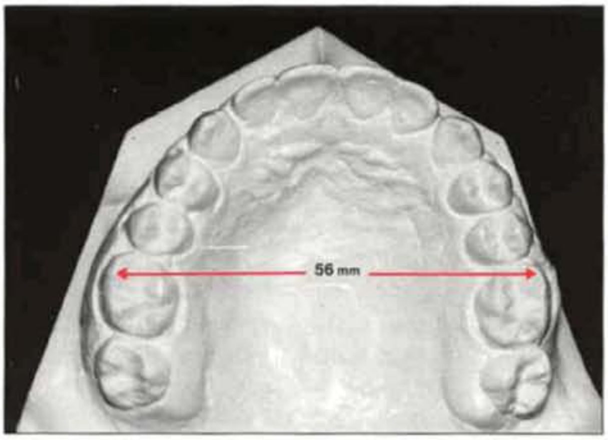

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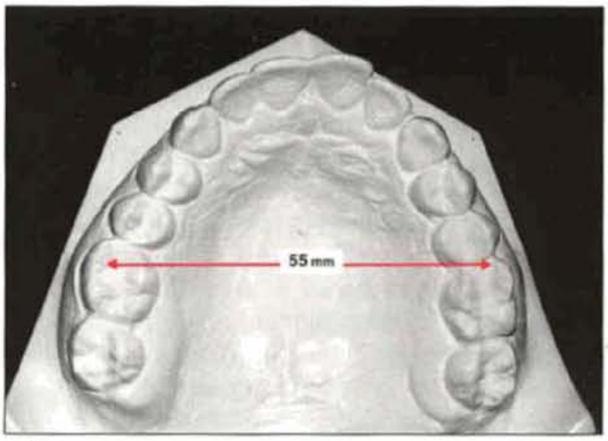

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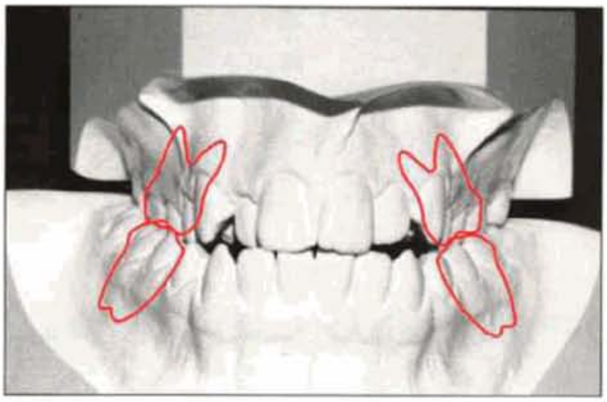


Fig 2-17 Skeletal posterior crossbite. Uprighting the molars would accentuate the crossbite.

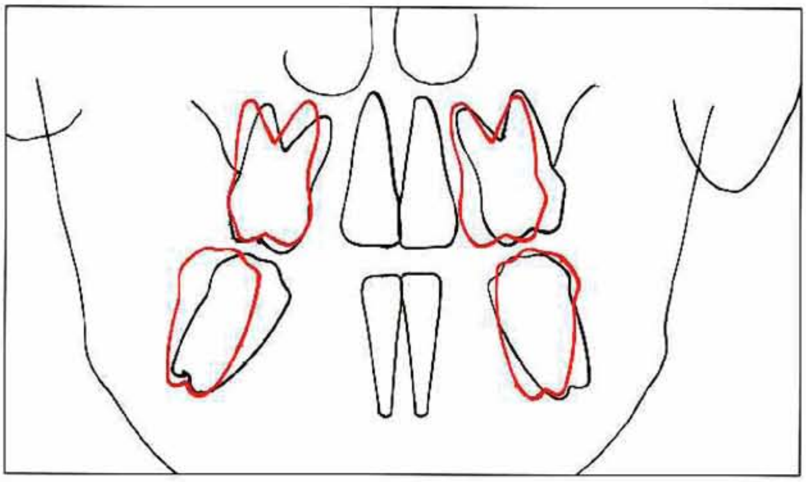


Fig 2-18 Transverse skeletal discrepancy. "Hidden" crossbite. Uprighting the molars to produce normal axial inclinations would create a crossbite (red).

these skeletal problems must be addressed either surgically or by rapid palatal expansion.

This chapter has considered, as a starting place for any orthodontic treatment planning, the desirable skeletal changes that may be envisioned as part of treatment. There are many unknowns, such as variations in growth, stability, and the magnitude of an orthopedic change that can be produced and maintained. Nevertheless, the skeletal changes are so important that one must make a prediction. Based on this best estimate, one can continually monitor patients and make appropriate modifications to the plan during treatment.

The emphasis of this book is on treatment planning and goal setting for nonsurgical patients. The same principles, however, hold true for those patients requiring orthognathic surgery. Bones are not positioned just to allow teeth to be aligned. Treatment planning should include facial and functional goals, considering the horizontal, vertical, and transverse dimensions. In fact, when planning the desired skeletal changes, it could be useful to mentally ignore the teeth, an exercise that would preclude one from making decisions that might be unfavorable to the face. The unknowns of making skeletal determinations should not prevent the orthodontist from first analyzing and then planning those procedures that would be best for the patient.

3

Chapter

The Treatment Occlusal Plane

After determining the optimal skeletal relationships, the next step in goal-planning is to determine the cant and level of the occlusal plane. The concept of an occlusal plane is a useful abstraction; it allows one to position the upper and lower teeth on a flat surface while recognizing that curvatures may exist in the posterior and anterior regions. The occlusal plane angle, or cant, can be measured from either the Frankfort horizontal or the mandibular plane; its level can be established as a ratio of the distance from the lower incisor to Me in relation to the vertical distance from the ANS to Me. The treatment plane of occlusion should not be confused with the cephalometric construct represented by a line drawn between the molars to a point bisecting the incisor overbite. Although such constructs can be useful in clinical outcome studies, they are not useful for determining the optimal relationship of the teeth.

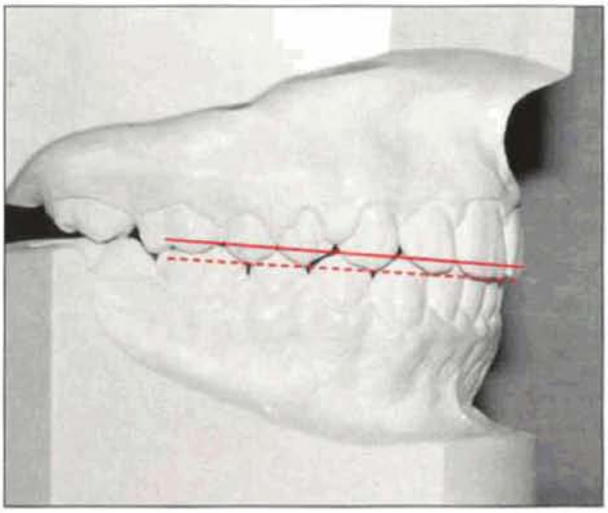
In normal occlusion there are two planes, the upper and the lower. The upper plane of occlusion connects the incisal edge of the upper central incisors with a point approximately 0.5 mm occlusal to the mesiobuccal cusp tip of the upper first permanent molars. The lower plane of occlusion connects the incisal edge of the lower central incisors with a point approximately 0.5 mm occlusal to the mesiobuccal cusp tip of the lower first permanent molars. For normal intercuspal relationships, the upper and lower planes of occlusion must be parallel and separated by about 2 mm (Fig 3-1).

Determining the Cant and Level of the Treatment Occlusal Plane

In establishing the treatment occlusal plane, artificial constructs will not be used; rather, treatment will be based on what is most beneficial to the patient. The following factors will be considered.

The Natural Plane of Occlusion

The purpose of establishing a natural plane of occlusion (NOP) is to maintain what is good in posterior axial inclinations and to make only minimal alterations as part of the treatment process. Many patients who present for treatment have relatively good posterior occlusion, and even in many patients treated for Class II or Class III mal-



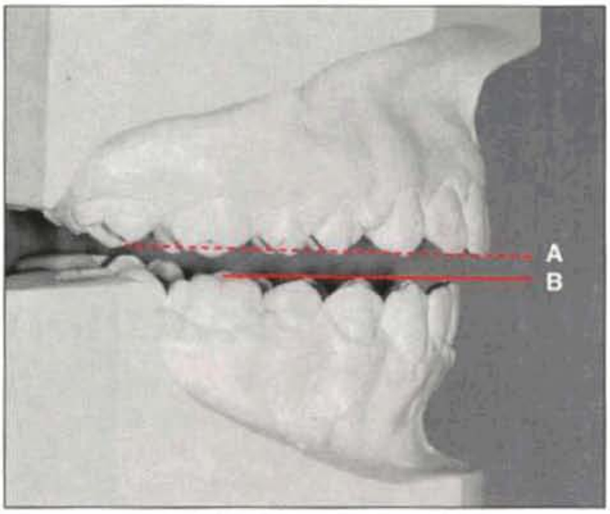


Fig 3-1 In normal occlusions, upper and lower planes are parallel. Left, Teeth in occlusion. Right, Teeth separated. In occlusion, the lower occlusal plane lies approximately 2 mm superior to the lower plane. A, Upper plane. B, Lower plane.

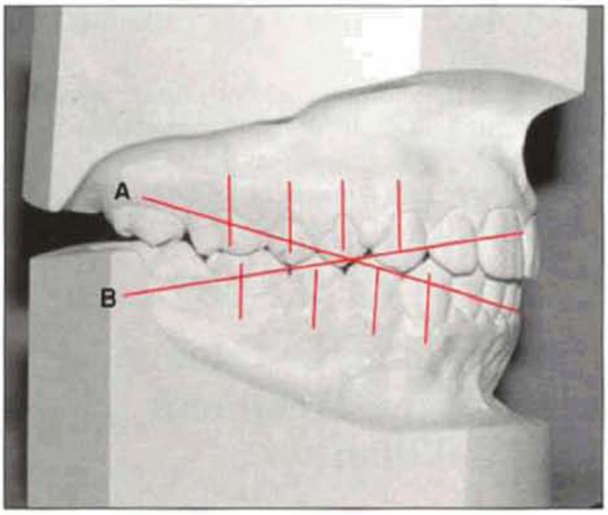


Fig 3-2 To maintain good occlusion, steepening (A) or flattening (B) of the occlusal plane would also require alteration of the posterior axial inclinations.

occlusion, the axial inclination of the posterior teeth should be maintained. If the goal for every patient was perfect occlusion with excellent intercuspation, changing the cant of the plane of occlusion to achieve that goal would also require altering the axial inclinations of the posterior teeth to maintain the occlusion (Fig 3-2). This could lead to problems of instability as well as making treatment more difficult.

In some patients, from the first molar forward the dental arches are relatively flat. In these patients, a line connecting the central fossae and embrasures could be used to estimate the natural plane of occlusion. However, since most arches have some curvature, this arbitrary line is not very accurate, and it bears no relation to the axial inclinations of the teeth.

To study the mesiodistal axial inclinations of the teeth, study casts and radiographs are very useful, while the 45-degree headfilm offers the opportunity to evaluate posterior axial inclinations in an oriented record (Fig 3-3). Beginning

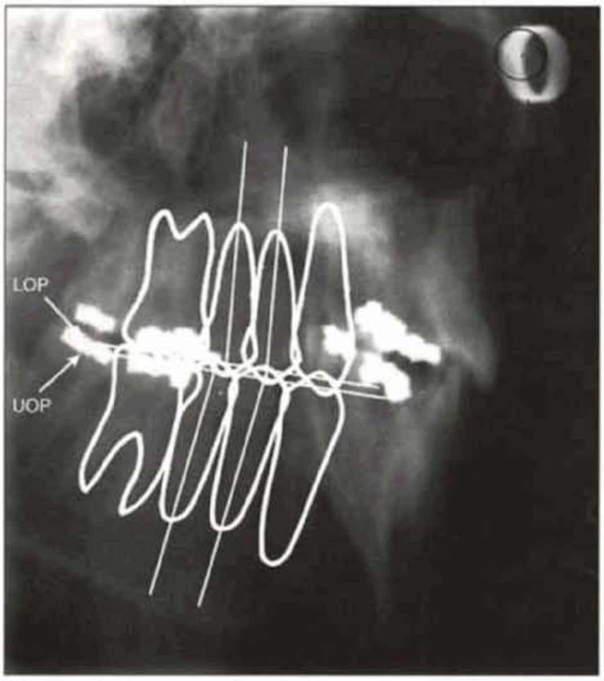


Fig 3-3 A 45-degree headfilm can be used to establish upper and lower natural planes of occlusion. Axial inclinations of all teeth in each posterior segment are considered.

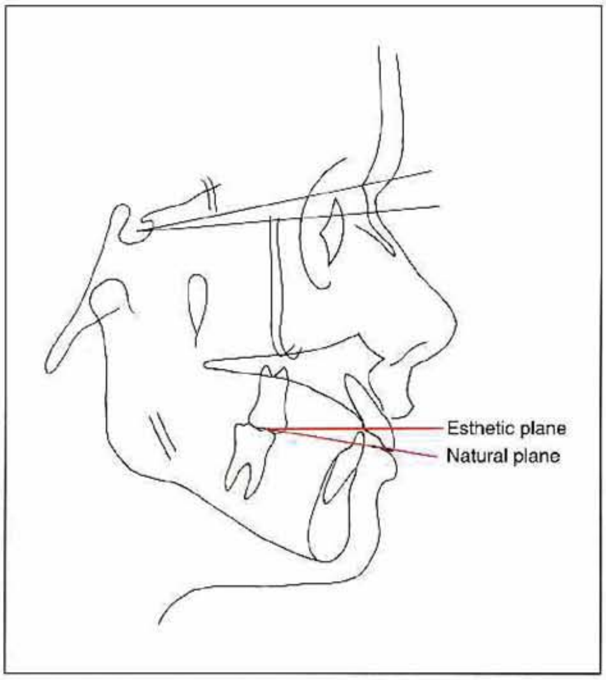


Fig 3-4 Natural and esthetic planes of occlusion diverge. Selection of one or the other as the treatment plane of occlusion presents problems. Treating to the natural plane displays too much upper incisor.

with the premolars, the entire posterior segment should be examined. Upper and lower premolars are typically perpendicular or may be inclined slightly mesial to the occlusal plane. It is not enough, however, to look only at the premolars; one should then move further back to the first molars. Generally, the distobuccal cusp of the upper first molar will be occlusal to the plane of occlusion, while the mesial and distal cusps of the lower first molar will be parallel to the plane of occlusion. On a lateral headfilm, both upper and lower molar long axes lean slightly mesial to the plane of occlusion. With input from all regions of the buccal segment, one could then establish a natural plane of occlusion for each arch, recognizing what it truly is: a plane that minimally alters the axial inclination of the posterior teeth. Of course, individual teeth in the buccal segment could be malpositioned, thus requiring individual changes to the axial inclination; if so, these particular teeth should not be used to establish the natural plane of occlusion. In most patients it is possible to establish one natural plane of occlusion, and since the upper and lower planes must be parallel, only one plane, the upper natural plane of occlusion, is shown. If a large divergence exists, it is best to show both the upper and lower natural planes of occlusion and to postpone establishment of the final treatment plane of occlusion (Fig 3-1) pending other considerations, which are discussed below.

The Esthetic Plane of Occlusion

The upper incisor commonly lies about 3 mm below a relaxed upper lip, and a line connecting the distobuccal cusp tip of the upper first molar and a point 3 mm below the upper lip represents the esthetic plane of occlusion. The esthetic and natural planes of occlusion shown in Fig 3-4 are widely divergent. When the esthetic plane is not identical to the natural plane and the esthetic

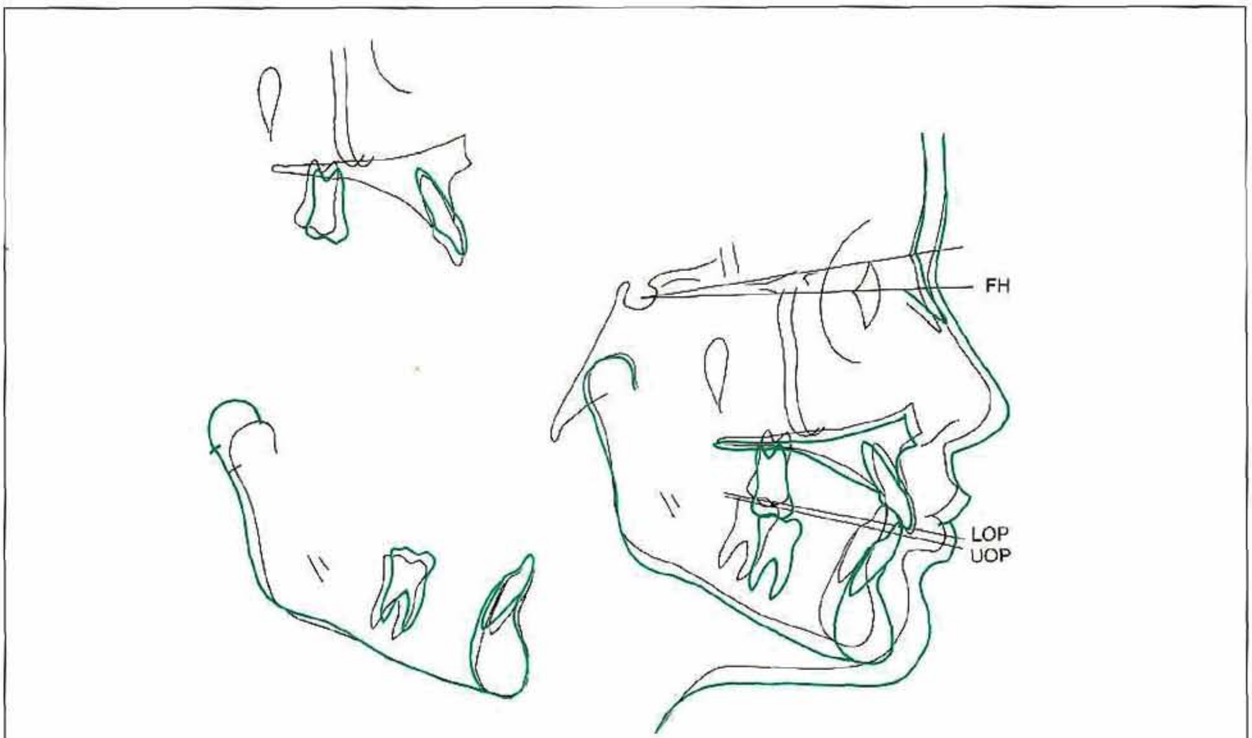


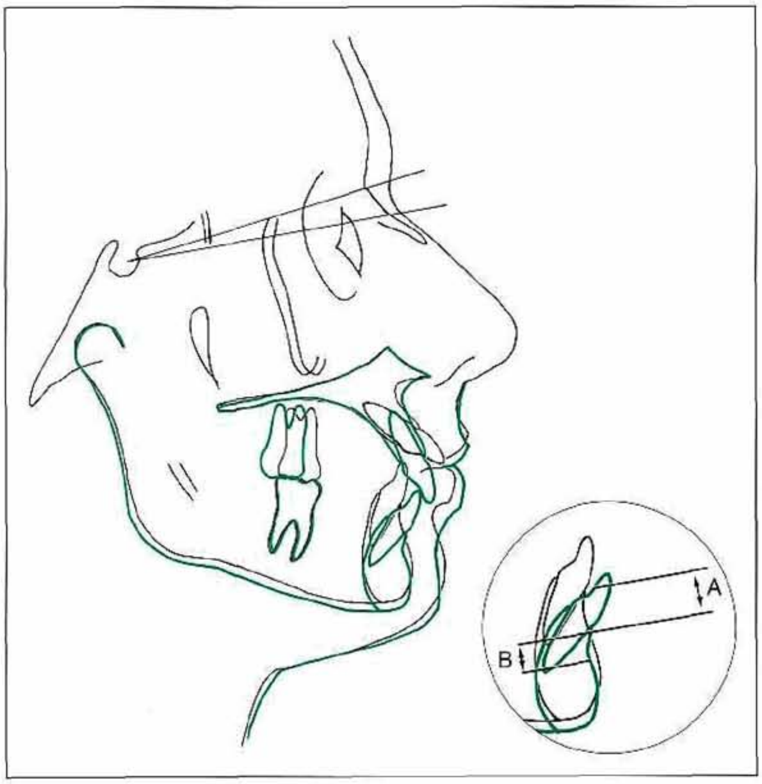
Fig 3-5 Patient KS. Flattening the plane of occlusion improved esthetics by incisor intrusion. (FH = Frankfort horizontal; LOP = lower occlusal plane; UOP = upper occlusal plane.)

plane is used as the treatment plane of occlusion, a change in the axial inclinations of the teeth is required (this may or may not be desirable). However, if the natural plane is used as the treatment plane of occlusion, the result will be an excessive amount of incisor exposure. Thus, the treatment plane of occlusion should not be determined until all important factors have been considered.

The amount of upper incisor exposure is intimately related to the vertical dimension, which can be excessive. If surgery or other means of reducing vertical dimension is not planned, consideration can be given to altering the cant and level of the occlusal plane. The upper incisors of patient KS project too far occlusal below the upper lip (Fig 3-5). One solution to reducing the amount of tooth exposure is to flatten the plane of occlusion; this was accomplished with an occipital headgear designed to pull anterior to the center of resistance of the maxillary arch. Note that not only have the incisors intruded, but that the axial inclinations of all of the posterior teeth have changed. Because the roots of these teeth have been moved further distally, this result represents overtreatment of a Class II malocclusion. Moreover, the headgear therapy had the effect of raising the level of the occlusal plane, inhibiting upper molar eruption relative to lower molar eruption. The decreased incisor exposure also is related to the increased lip length resulting from growth during treatment.

If the vertical dimension is too great, the problem may have to be resolved by orthognathic surgery; otherwise, as we have seen, the incisor position may be compromised. Incisor positioning is addressed below relative to building a curve of Spee into the arch.

Fig 3-6 Steepening the plane of occlusion reduces the attached gingiva in the lower incisor region, leading to possible periodontal problems. A, Attached gingiva before treatment. B, Attached gingiva after treatment.



— original position
— treatment outcome

Distribution of the Alveolar Process

It has already been observed that, in general, the distribution of the alveolar process in the upper and lower arches can be described as a ratio of the distance from the lower incisor to Me in relation to the distance from the ANS to Me. On average, this ratio is about 0.61. While one cannot blindly adhere to this ratio, clinical problems may result if there is too little alveolar process or attached gingiva in an arch.

For example, if a patient with a Class II malocclusion and a small vertical dimension is treated with Class II elastics, the plane of occlusion may be steepened. Associated with this steeper plane of occlusion is a shorter distance between the lower incisor and the mucobuccal fold, potentially leading to a periodontal problem. It is difficult for the patient with a reduced "lower dental height" to brush the teeth adequately; the frenum attachments come very close to the gingival margin of the lower anterior teeth, reducing the amount of attached gingiva. A severe disproportion of alveolar process associated with an improper occlusal plane could be detrimental to a patient's future periodontal health (Fig 3-6).

Altering the Occlusal Plane and Its Effect on the A–B Difference

The tracings in Figs 3-7a and 3-7b show almost identical degrees of hard tissue facial convexity (N–A–Pg). The anteroposterior occlusion is based not on the convexity of the face, but rather on the relationship of point A to point B relative to the occlusal plane. Note that in Fig 3-7a, which shows a relatively flat occlusal plane, the A–B difference is large, resulting in a Class II malocclusion. In Fig 3-7b, where the plane of occlusion is steeper, the A–B difference results in a slight Class III relationship. Figure 3-8 illustrates the effect of altering the occlusal plane on the A–B relationship: as the occlusal plane steepens, the A–B difference in the same skeletal pattern leads to more of a Class III occlusal relationship.

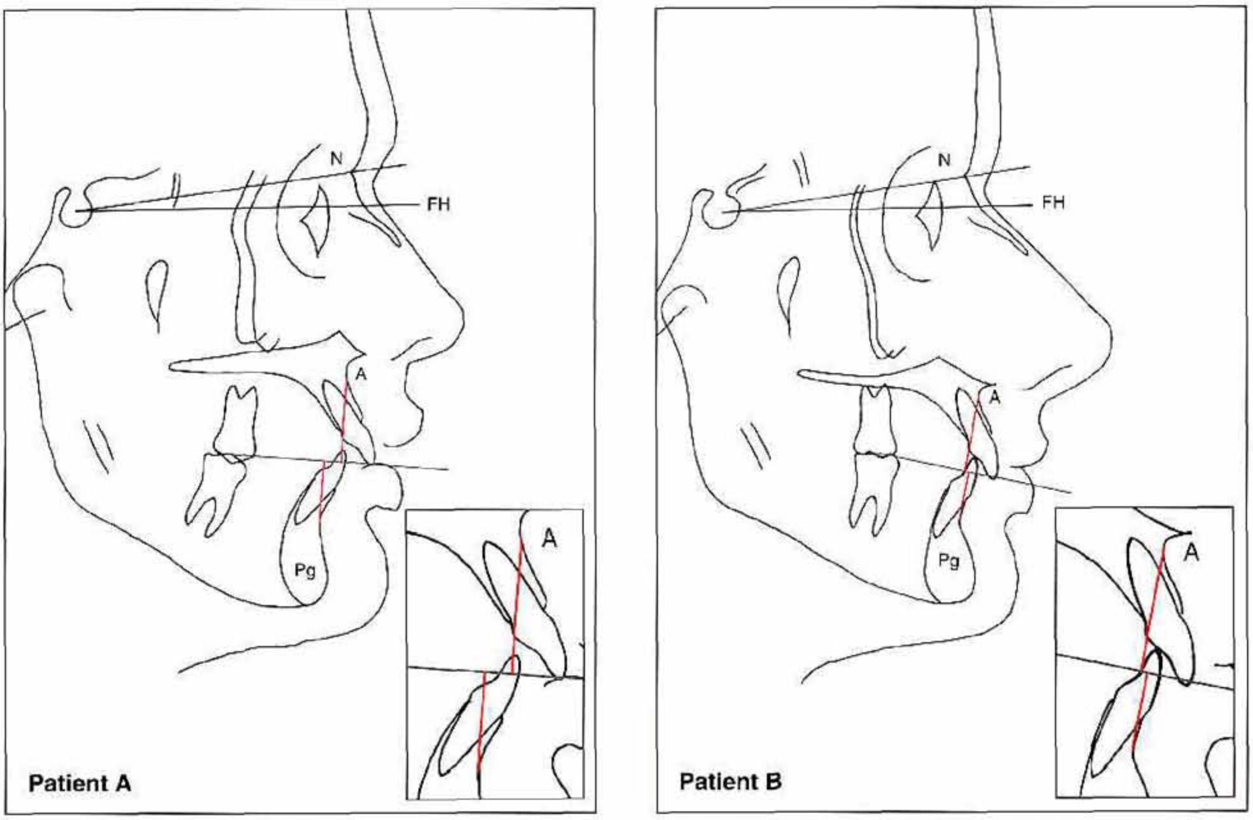


Fig 3-7 Patients A and B have similar N-A-Pg angles (4 and 5 degrees, respectively). The flatter occlusal plane in patient A leads to a Class II A–B relationship and a Class II malocclusion.

Thus, in a Class II patient, as the occlusal plane is steepened the A–B discrepancy is reduced, and treatment, at least in one respect, is easier. Conversely, the mechanics required to steepen the plane of occlusion will usually have the effect of rotating the mandible open (which usually is undesirable), exposing too much of the upper incisor, altering the natural plane of occlusion, and, in the process, changing the axial inclinations of the posterior teeth.

Nevertheless, one must consider the effect of altering the occlusal plane on the efficiency of treatment. While flattening the occlusal plane in a Class II patient could be desirable esthetically and could even represent a form of overtreatment, it might present unrealistic treatment goals due to the larger A–B discrepancy produced. On the other hand, if the plane of occlusion could be steepened slightly while all other objectives were met, the Class II correction would be greatly simplified.

What happens, one might ask, when there is growth? If vertical growth relative to the Frankfort horizontal occurs, does this growth help or hinder the Class II treatment? Once again, the answer depends on the cant of the plane of occlusion. In Fig 3-9, one can see that when there is growth, the cant of the occlusal plane determines the A–B relationship. Here, even vertical growth of the mandible can improve the A–B relationship when the plane of occlusion is steep. Since the cant of the occlusal plane determines the horizontal component of the A–B change, it has a direct influence on the occlusion and the face.

A number of factors should be considered when determining the most desirable treatment plane of occlusion: the natural plane of occlusion, the esthetic plane of occlusion, the distribution of the alveolar process, and the consequences of any given plane of occlusion on the A–B difference. In addition, other elements, such as jaw function, may be considered. There is no com-

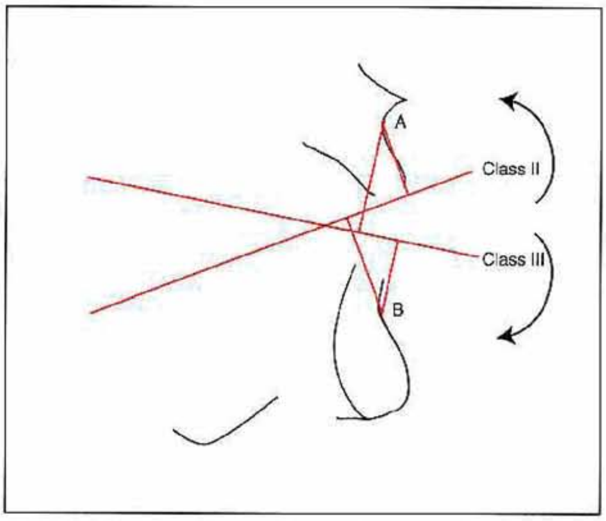


Fig 3-8 Rotating the occlusal plane counterclockwise increases the Class II tendency. Rotating the occlusal plane clockwise increases the Class III tendency.

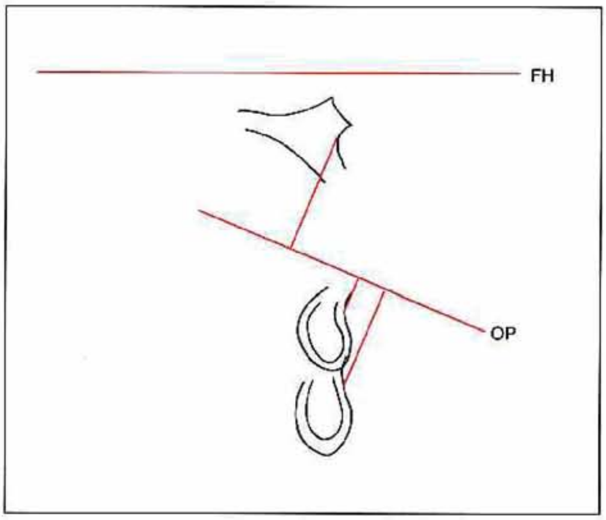


Fig 3-9 With a steep plane of occlusion, even the mandible that undergoes vertical growth still moves forward relative to the maxilla.

plete agreement on the relationship between the occlusal plane and incisal guidance, condylar motion, and overall function of the jaws; theories range from those espoused by the traditional gnathologists to some exciting new concepts developed by Kubein-Meesenberg and Nägerl. In the future one may have to pay more attention to the effect of jaw function in establishing a treatment occlusal plane. In fact, long-term stability of the occlusal plane may well be related to functional factors rather than to the major anatomic considerations guiding us at this time.

When determining the treatment plane of occlusion, one must give consideration not only to its cant but also to its level. In nongrowing patients, the amount of intrusion possible for the posterior teeth is limited. Thus, in these patients, the level of the occlusal plane for posterior teeth cannot be significantly altered. In growing patients, however, the level of the plane of occlusion can be altered. Because there may be an intermaxillary growth space separating the molars, it is possible to erupt upper and lower molars differentially (see Chapter 1). These molars can be held with headgear, bite blocks, or chin caps, any of which would influence their eruption. For example, if a patient shows excessive upper incisor exposure and no discrepancy exists in the level between the anterior and posterior teeth, an occipital headgear can be used to hold the upper arch, thus allowing more eruption of the lower arch.

The final determination of the cant and level of the occlusal plane is made after all factors have been considered. In many instances the decision becomes a compromise, ie, what produces good facial esthetics may alter axial inclinations of the posterior teeth. For example, a decision to maintain the original axial inclinations and the occlusion of the posterior segments may mean some compromises will be made in facial esthetics. Judgment must be used to resolve the dichotomy between facial esthetics and the natural planes of occlusion.

It should be reemphasized that the treatment plane of occlusion should be one that is beneficial to the patient, and not just an artificial construct. It should take into consideration a number of factors, including the axial inclinations of the posterior teeth, which, if normal, should be maintained; the stability of the treatment result; facial esthetics; periodontal considerations; and the effect on the A–B relationship. Of parallel concern are the limitations of treatment, including appliance therapy and patient cooperation.

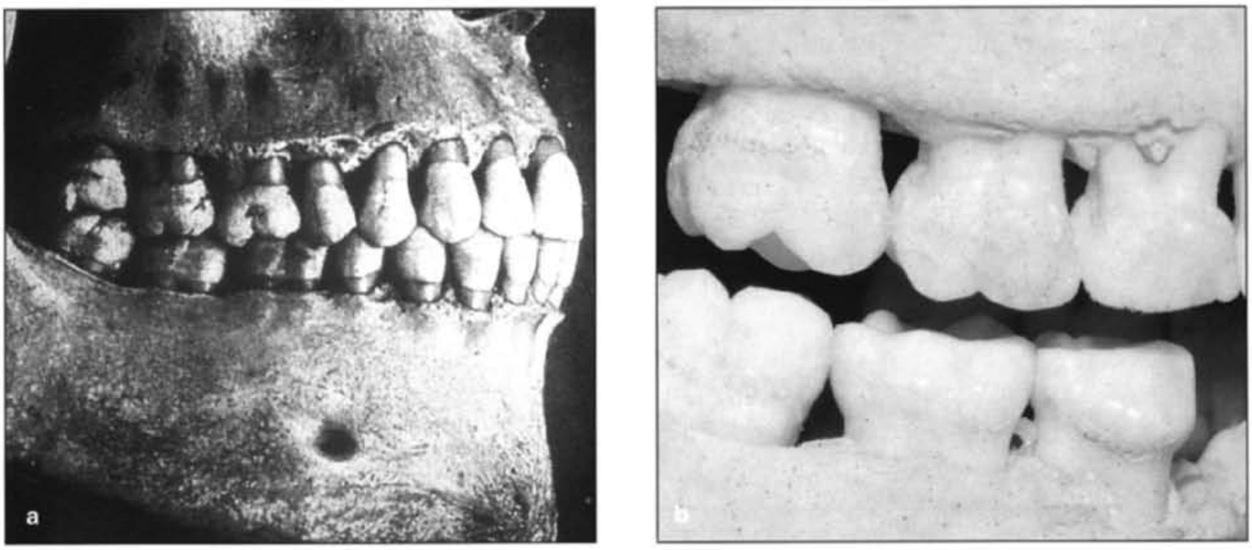


Fig 3-10 A curve of Spee distal to the first molars is common. a, Adult skull. The upper third molars lean distally, while the lower third molars lean mesially. Second molars exhibit similar axial inclinations in adolescents. b, Youth (7-year-old) skull. The first molars show immature axial inclinations, ie, the upper first molars lean distally and the lower first molars lean mesially.

Occlusal Curvatures

When looking at well-developed occlusions in the sagittal view, a slight curve of Spee can usually be detected. Because of functional, esthetic, and even arch-length considerations, some curve of Spee may even be desirable.

A developing child may not demonstrate the axial inclinations normally found in an adult. At 6 years of age, for example, the upper first molar may have a distal axial inclination and the lower first molar may have a slight mesial inclination. Later, as second molars erupt, the upper second molars lean distally and the lower second molars lean mesially. The same relationships are seen with erupting third molars (Fig 3-10). These immature axial inclinations are nature's attempt to fit the teeth into the arch before there is adequate room. In developing dentitions, these axial inclinations should usually be maintained; that is, a curve of Spee is normal in the posterior region. In Class II patients, if the distobuccal cusp is brought down on an immature first or second molar, the entire dentition is driven forward, thus increasing the Class II malocclusion. On the other hand, in the lower arch it may be desirable to upright molars so as to gain additional arch length and flatten the plane of occlusion, improving esthetics and possibly leading to overtreatment.

In other situations it is desirable to build in some anterior curve of Spee. Figure 3-11 shows a patient with a large vertical dimension, a large interlabial gap, and upper incisors that project too far occlusal relative to the lip. Ideally this patient should be treated by orthognathic surgery to reduce the vertical dimension. However, the patient declined surgery, and hence a compromise was achieved that involved building an anterior curve of Spee into the occlusal plane. Note that the vertical dimension was maintained, the upper incisors were intruded so that they have a better relationship to the lip, and the posterior curve of Spee was maintained. In addition, the intrusion produced an anterior curve of Spee to improve the facial esthetics (Fig 3-12).

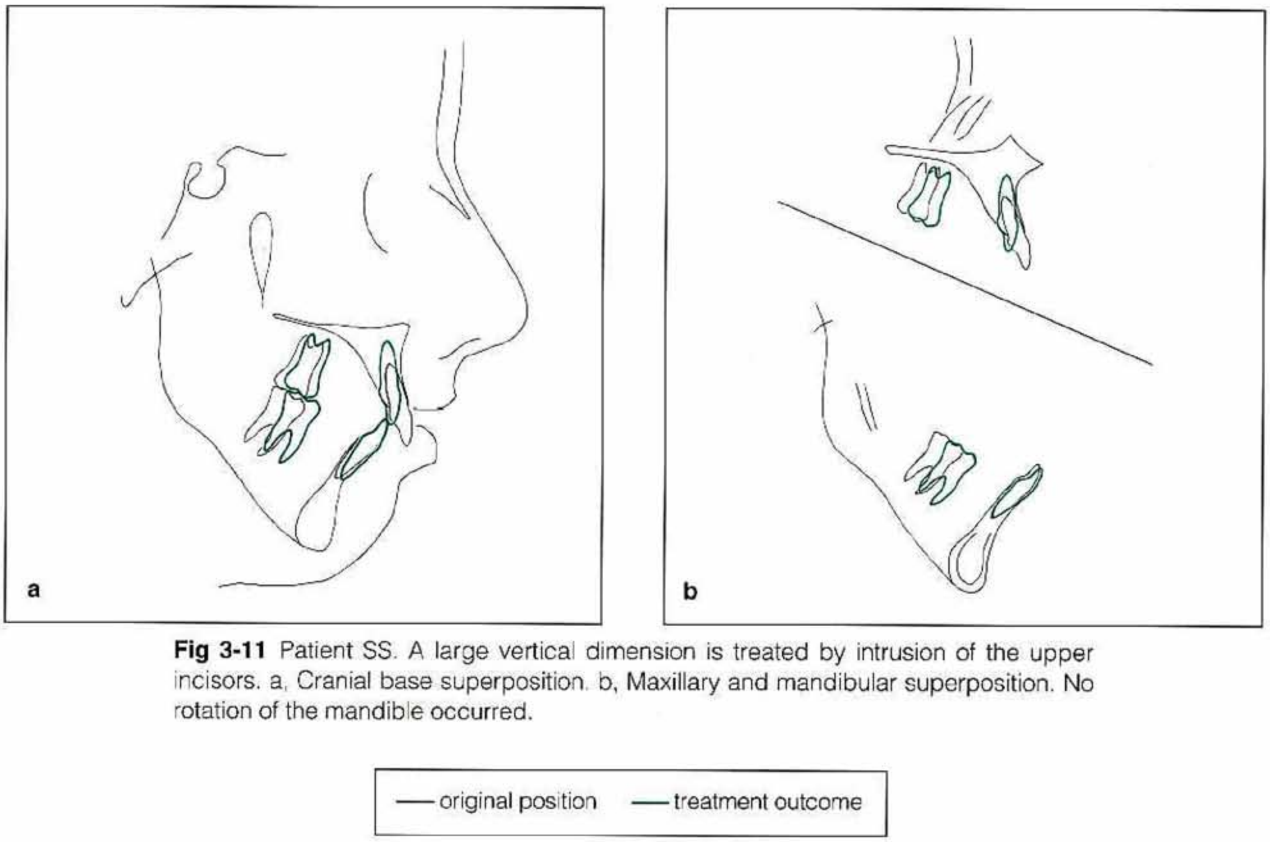


Fig 3-11 Patient SS. A large vertical dimension is treated by intrusion of the upper incisors. a, Cranial base superposition. b, Maxillary and mandibular superposition. No rotation of the mandible occurred.

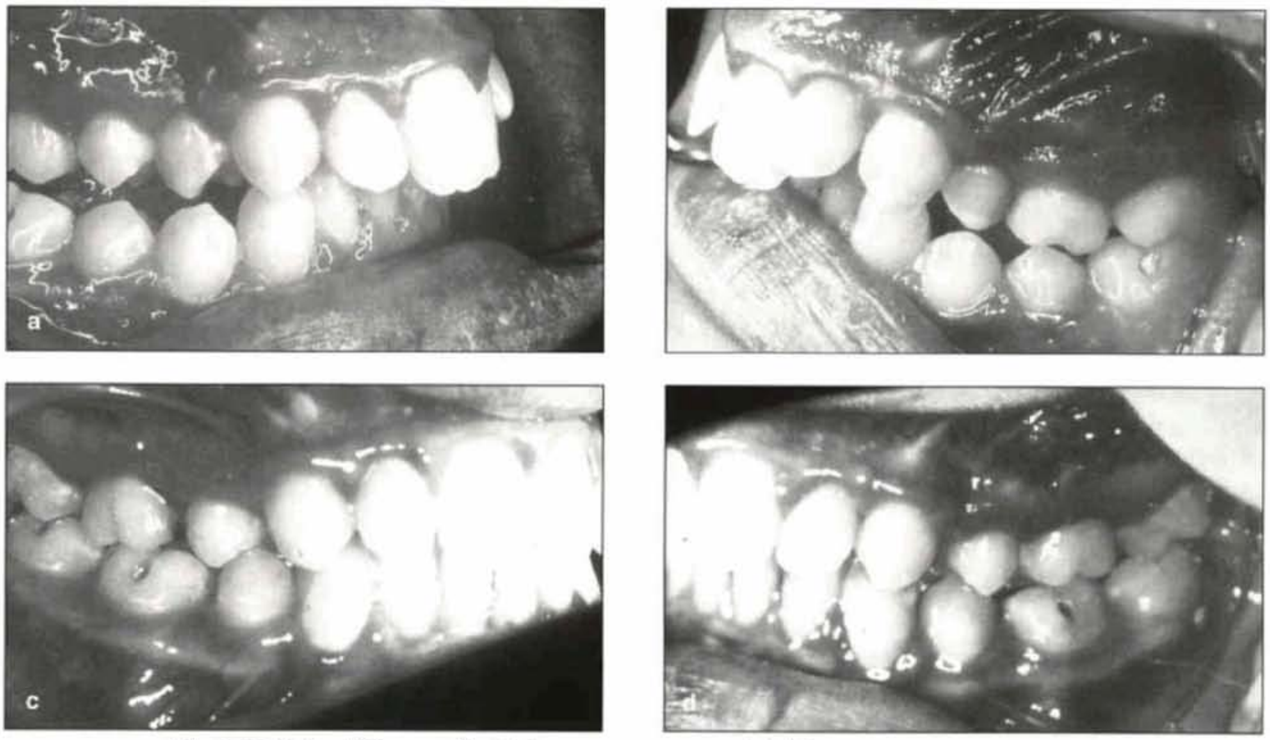


Fig 3-12 Patient SS. a and b, Before treatment. c and d, After treatment. Note anterior curve of Spee to improve esthetics.

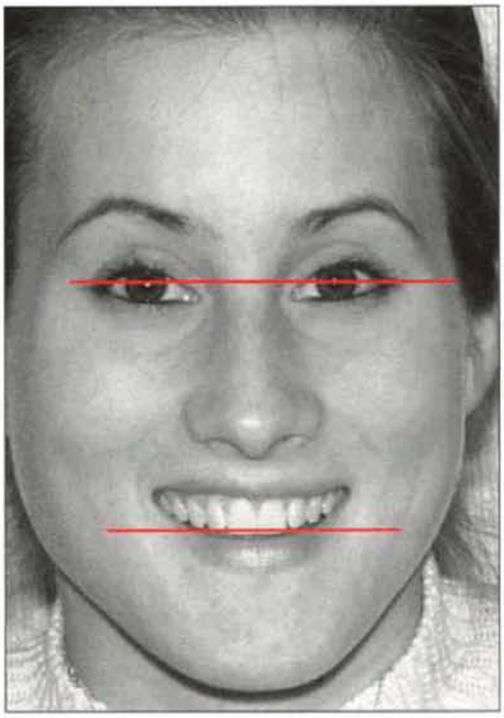


Fig 3-13 Frontal view of occlusal plane shows parallelism to a line connecting the pupils of the eyes; the lower lip line also parallels the occlusal plane in the frontal view.

There is an old tradition in orthodontics that lower arches should be leveled (no curve of Spee) during treatment. The history of this concept and its rationale are somewhat obscure; it probably relates to early attempts at deep overbite correction before effective intrusion mechanics were available. Also, a level arch aids in the sliding mechanics characteristic of some extraction therapy. As has been seen, indiscriminate leveling in the lower arch can produce undesirable side effects, including the rotating open of the mandible. Building in some occlusal curvature can be desirable for both esthetics and function.

Occlusal Plane: Frontal Aspect

By definition, the occlusal plane is three-dimensional, and hence its cant in the frontal view must also be considered. As with the lateral view, both structural and esthetic considerations can be used to establish a treatment plane of occlusion in the frontal view. The natural plane of occlusion is found by connecting points on the cusp tips or fossae between the right and left posterior teeth. Since it is difficult to mechanically extrude or intrude posterior teeth unilaterally without surgery, this natural plane is useful in establishing the desired treatment plane of occlusion. Individual teeth that are occlusally malaligned should be disregarded.

The esthetic plane of occlusion in the frontal view is best determined by soft tissue relationships. The plane of occlusion is parallel to lines representing the lower lip, connecting the corners of the mouth, or connecting the pupils of the eyes (Fig 3-13). The use of special glasses with an adjustable wire that can be aligned with the pupils of the eyes and shows on a posteroanterior headfilm allows for registration of the interpupil line on the radiograph (Fig 3-14).

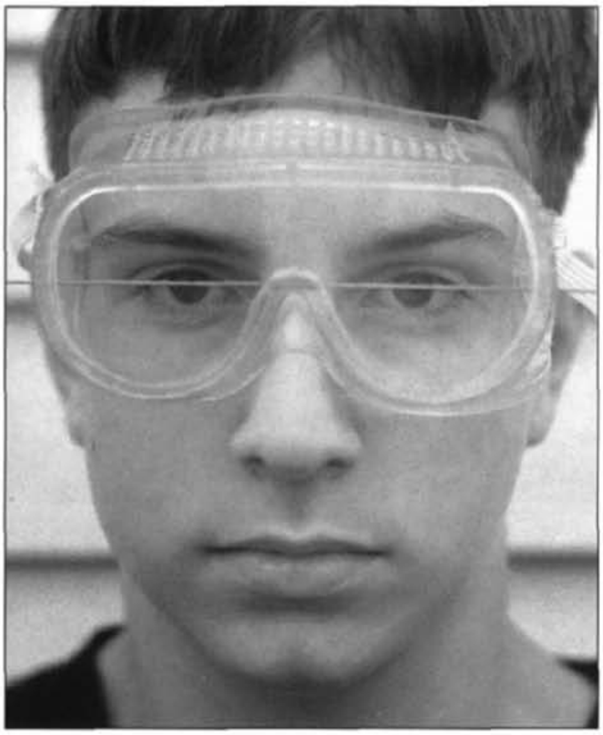


Fig 3-14a Glasses with a .036-inch wire connecting the pupils of the eyes.

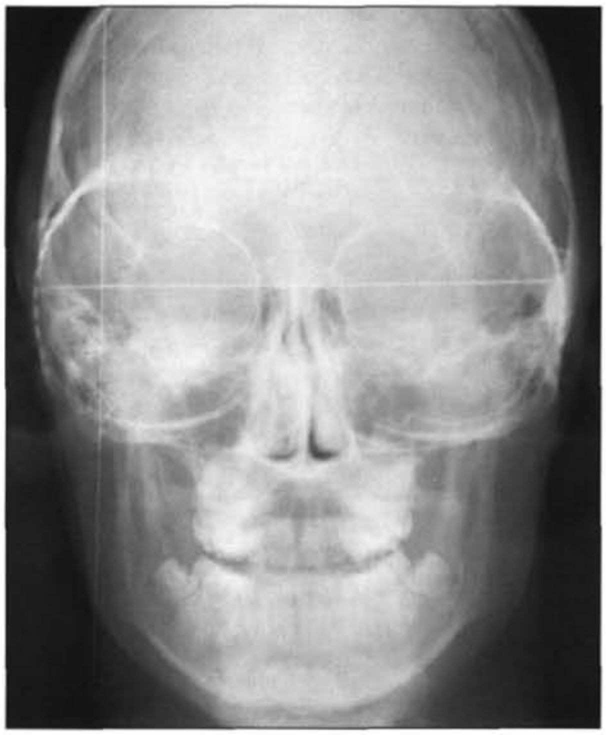


Fig 3-14b Wire on glasses is a horizontal reference line on the posteroanterior headfilm.

Sometimes skeletal or soft tissue constructs have been used to establish a horizontal plane. Bilateral points are connected in the cranial base, in the zygoma, or in the maxilla. In many patients, such lines may not be parallel to each other. They lack validity for determining an esthetic plane of occlusion in the frontal view since they often do not correlate with the soft tissue structures of the lips and the corners of the mouth. Patients evaluate the cant of the frontal occlusal plane by these soft tissues, not by arbitrary lines drawn between bilateral skeletal or soft tissue points. The further away from the teeth the bilateral points and their connecting lines lie, the less likely the patient is to use them as a reference.

The frontal view of the desired treatment plane of occlusion has a cant that considers both the natural and the esthetic planes. If too great a discrepancy exists between the natural and esthetic planes or between the interpupil line and other lines describing the horizontal orientation of the face and head, orthognathic surgery may be required.

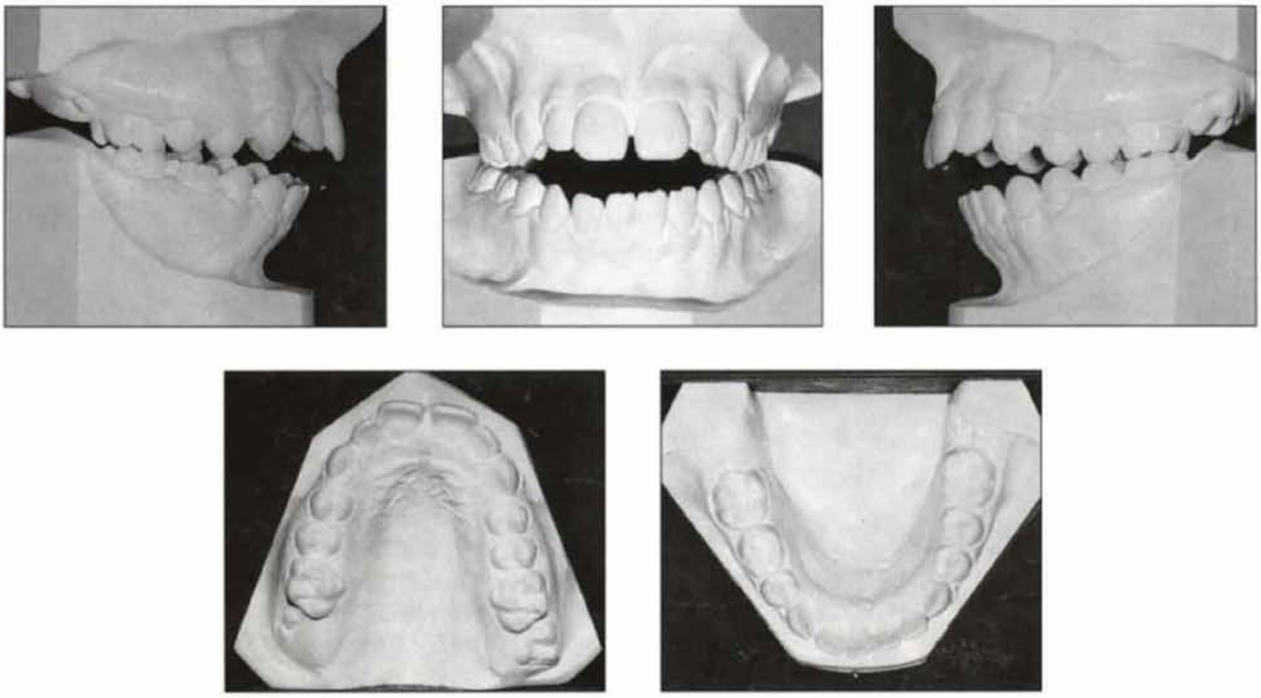
Furthermore, in the frontal view there are occlusal curvatures in the posterior teeth; the upper molars tend to lean buccal and the lower molars tend to lean lingual, producing a curve of Monson. When these curvatures are too extreme, expansion of the maxilla or orthognathic surgery, if required, is needed to correct these axial inclinations.

Treatment Planes of Occlusion

Establishment of a desirable treatment plane of occlusion requires careful consideration of all factors, and hence it is a value judgment. The cases that follow demonstrate this interactive and sometimes subjective decision-making process.

Fig 3-15 Patient LF. a, Dental casts before treatment. b, Dental casts after treatment. c, Facial photos: before treatment and after treatment. d, Before-treatment headfilm tracing showing upper and lower natural planes of occlusion. e, Before-treatment and after-treatment headfilm tracings superposed.

a

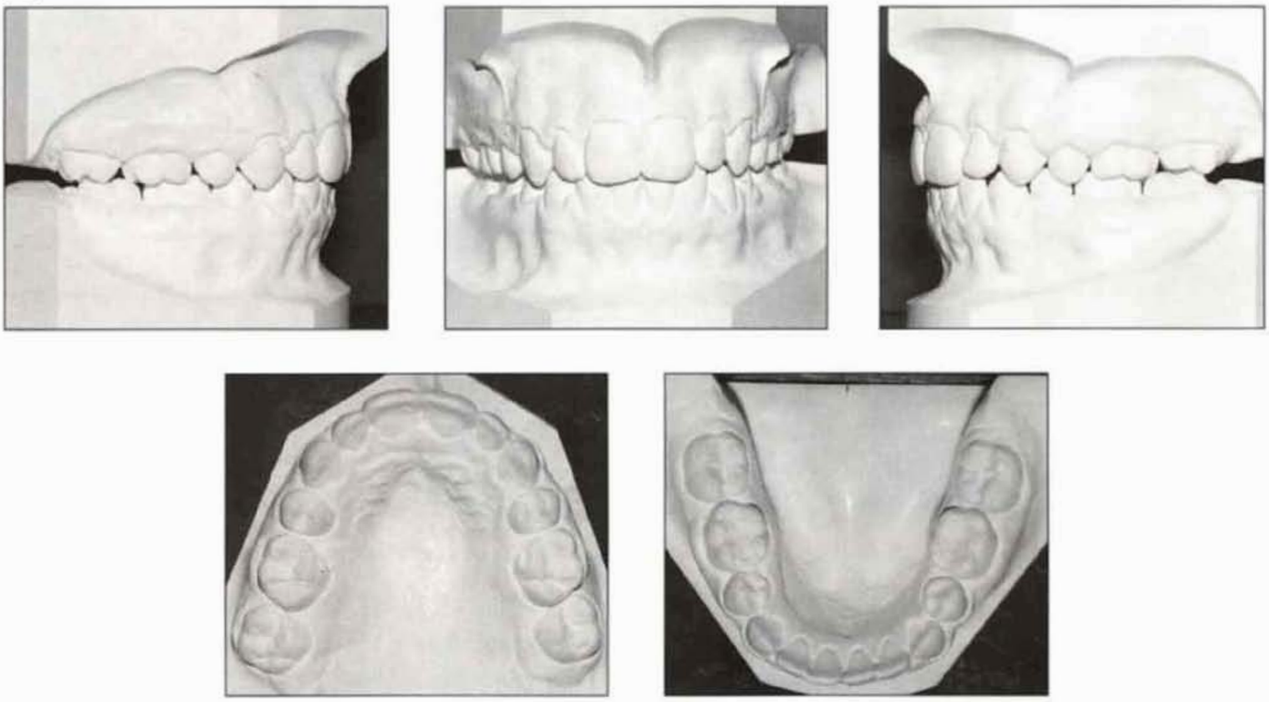


The patient with an open bite shown in Fig 2-14 exhibits two natural planes of occlusion. What would be the best treatment plane? The upper natural, the lower natural, or one that represents a compromise? The answer becomes obvious when the esthetic plane of occlusion is considered. The ideal treatment plane coincides with the upper natural plane, providing typical incisor exposure to the lip. The chin cap was used to rotate the mandible closed, flattening the lower natural plane and making it parallel to the upper natural plane. In addition, the large vertical dimension problem was addressed. In some patients, orthognathic surgery to rotate the mandible may be required to achieve this occlusal plane correspondence.

What should the cant of the treatment occlusal plane be on this type of patient, where surgical or orthodontic rotation has not been achieved? Although the vertical dimension problem is not solved, it is better to treat using the upper plane of occlusion (for good incisor-lip esthetics) as a guide by flattening the lower plane of occlusion. Since this is not produced by mandibular rotation, the lower arch must be erupted in the anterior. One method used to accomplish this is a "J" hook occipital headgear to the lower arch.

Patient LF has an anterior open bite with anterior occlusal curvature (Fig 3-15). The upper and lower natural planes of occlusion (U and L, respectively) diverge. Since the incisors lie in infraclusion to their respective occlusal planes, the open bite is greater than the occlusal plane divergence (Figs 3-15a and 3-15d). An anterior tongue seal is present during swallowing, and the relaxed lip position tracing shows both a large interlabial

b



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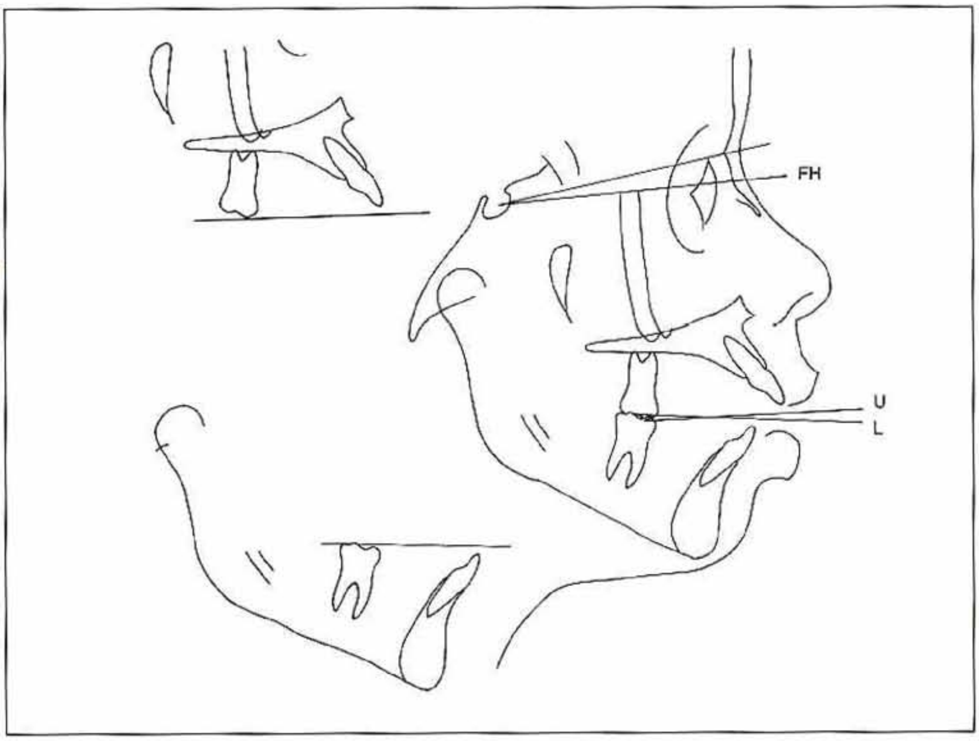

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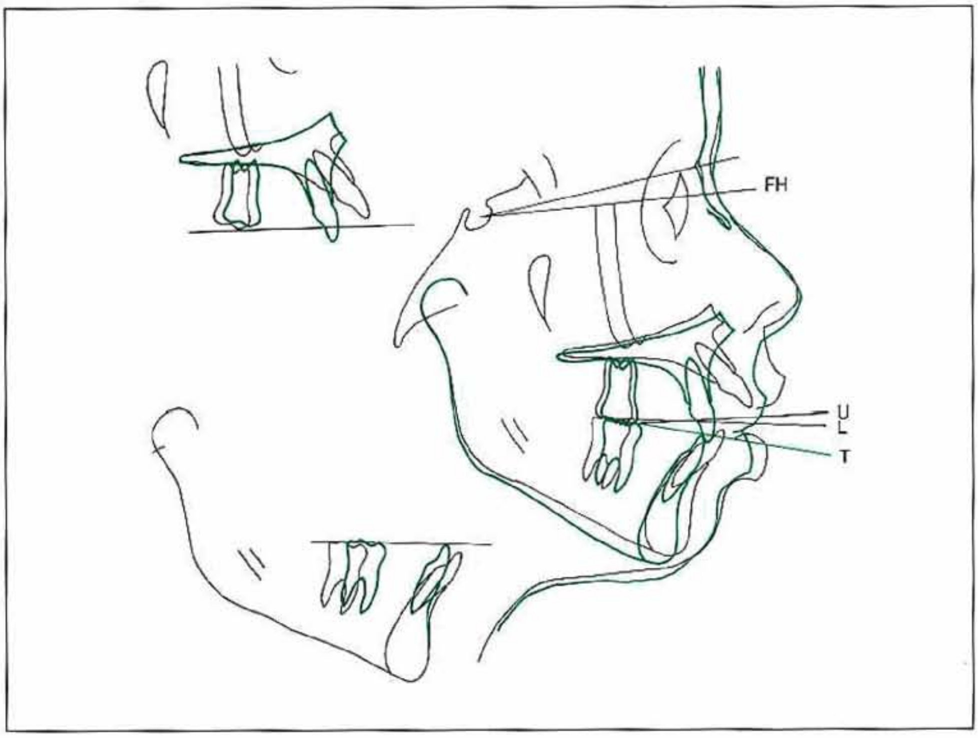


— original position — treatment outcome

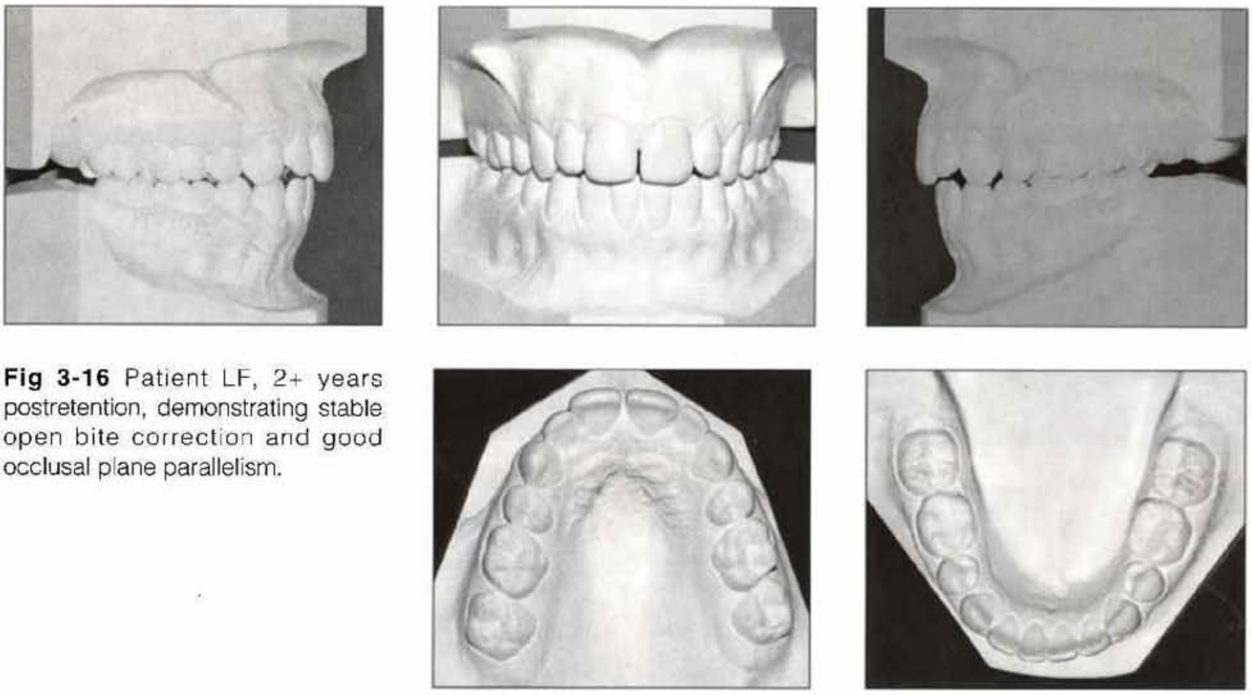


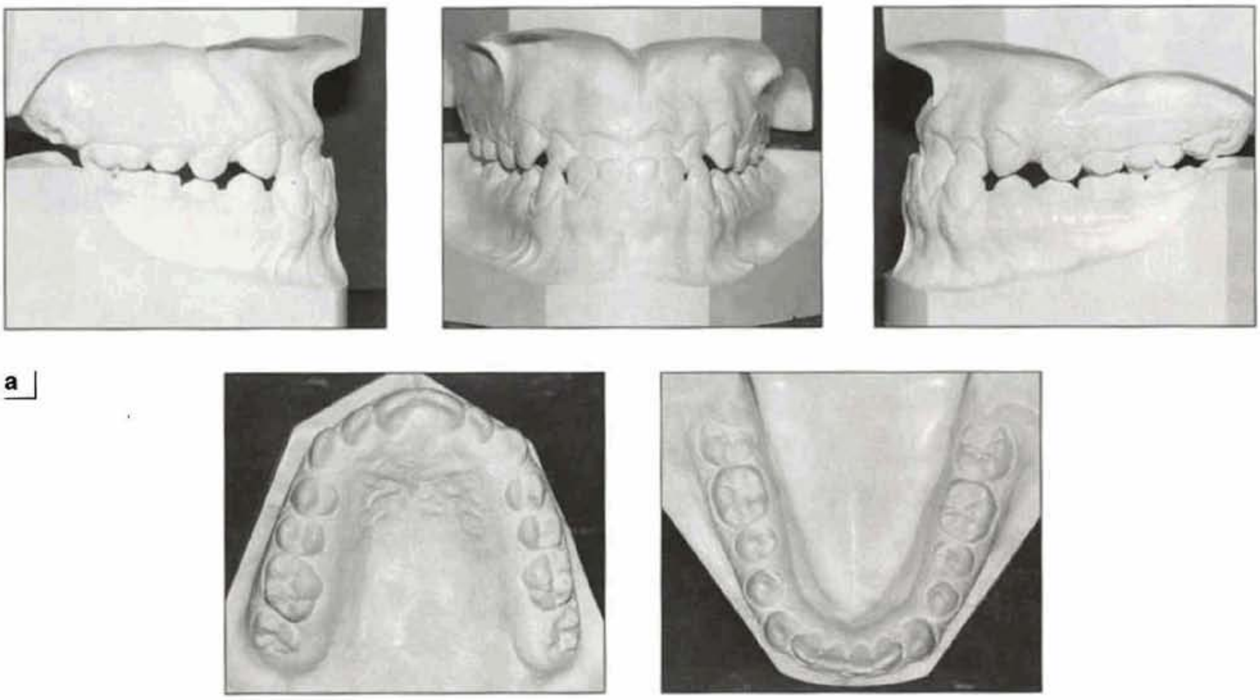
Fig 3-16 Patient LF, 2+ years postretention, demonstrating stable open bite correction and good occlusal plane parallelism.

gap and no incisal display. What is the most desirable treatment occlusal plane? Unlike the last patient, in this patient the lower natural plane is the best solution since it offers an esthetic advantage: as the upper incisors are brought into occlusion, they are given normal exposure. In addition, the steeper lower plane improves the A–B relationship, which is helpful in treatment of a Class II patient.

The before and after superposed tracings show the extrusion of the upper incisors and the steepening of the upper natural plane of occlusion; the lower natural plane of occlusion was maintained (Fig 3-15e). Extraction of premolars allowed for reduction in lip protrusion and interlabial gap. The concomitant improvement in lip closure and function most likely was responsible for the stable correction of the open bite. Although occipital headgear was used to control the vertical dimension, the mandible was rotated open somewhat during treatment. This is of course undesirable, since it increases occlusal plane divergence. The tendency of the mandible to rotate closed after treatment, however, adds to the stability of the open bite correction. The casts of patient LF after nearly 3 years of retention are shown in Fig 3-16. The open bite remains closed, while a small diastema is present between the upper central incisors.

Patient BF has a Class III malocclusion characterized by overclosure and a large freeway space (Fig 3-17). When the patient is placed in centric relation, both retrusion and downward and backward descent of the mandible results. In centric occlusion there is lack of parallelism of the upper and lower occlusal planes. This problem can be solved by rotating the mandible open (Fig 3-18). Thus, correspondence of occlusal planes does not require tooth movement to alter the cant of the upper or lower occlusal planes. An additional benefit of the rotation is improvement of the anteroposterior relation of the maxilla to the mandible. A comparison of the tracings in Figs 3-17b and 3-18b shows marked improvement in incisor underjet and molar occlusion (a small mesial shift is present initially). What appears at first to be a surgical case can be treated by orthodontics alone. As was pointed out in Chapter 2, rotating a mandible open may not always be stable. In this patient, the overclosure of the mandible and the large freeway space are good indications for increasing the vertical dimension.

Fig 3-17 Patient BF in centric occlusion. a, Dental casts in centric occlusion. b, Lateral headfilm tracing. Upper (U) and lower (L) natural planes of occlusion diverge.



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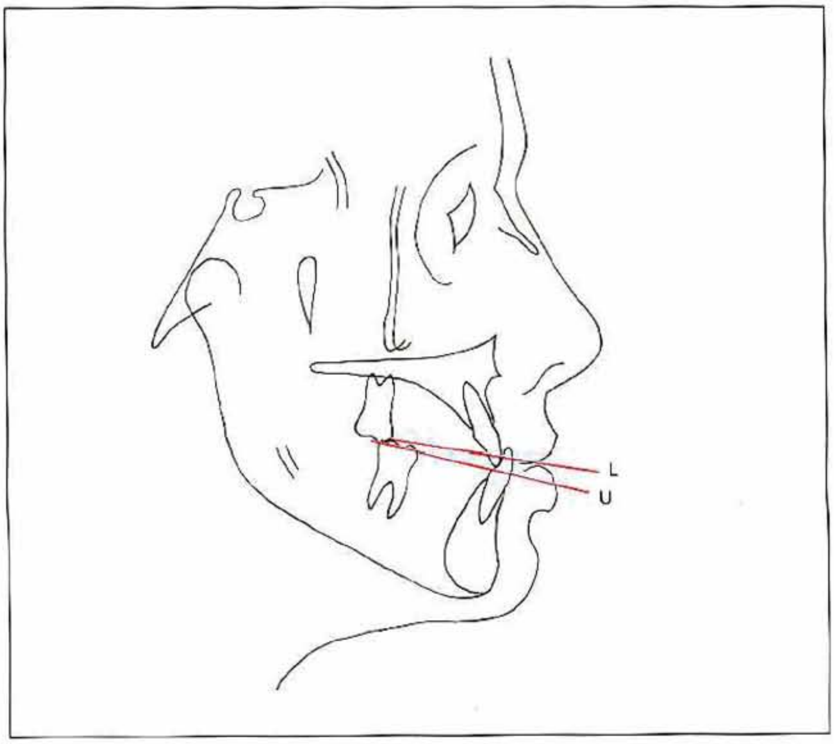

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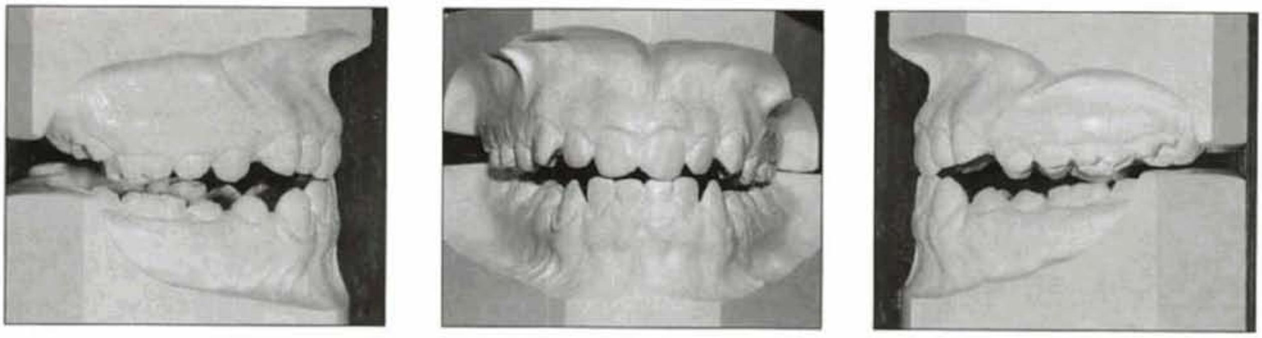
Fig 3-18 Patient BF in centric relation. a, Dental casts in centric relation position. b, Lateral headfilm tracing. Rotating mandible open produces parallelism of upper (U) and lower (L) natural occlusal planes. T = treatment plane of occlusion.



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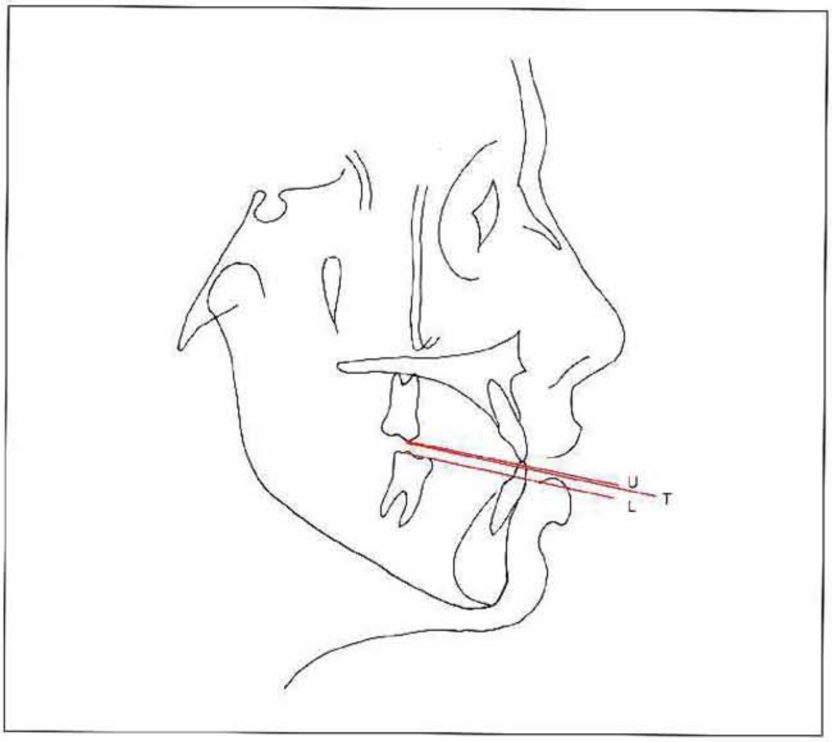

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Fig 3-19 Patient KS. Class II malocclusion with a deep overbite. a, Dental casts before treatment. b, Dental casts after treatment. c, Facial photos before and after treatment.

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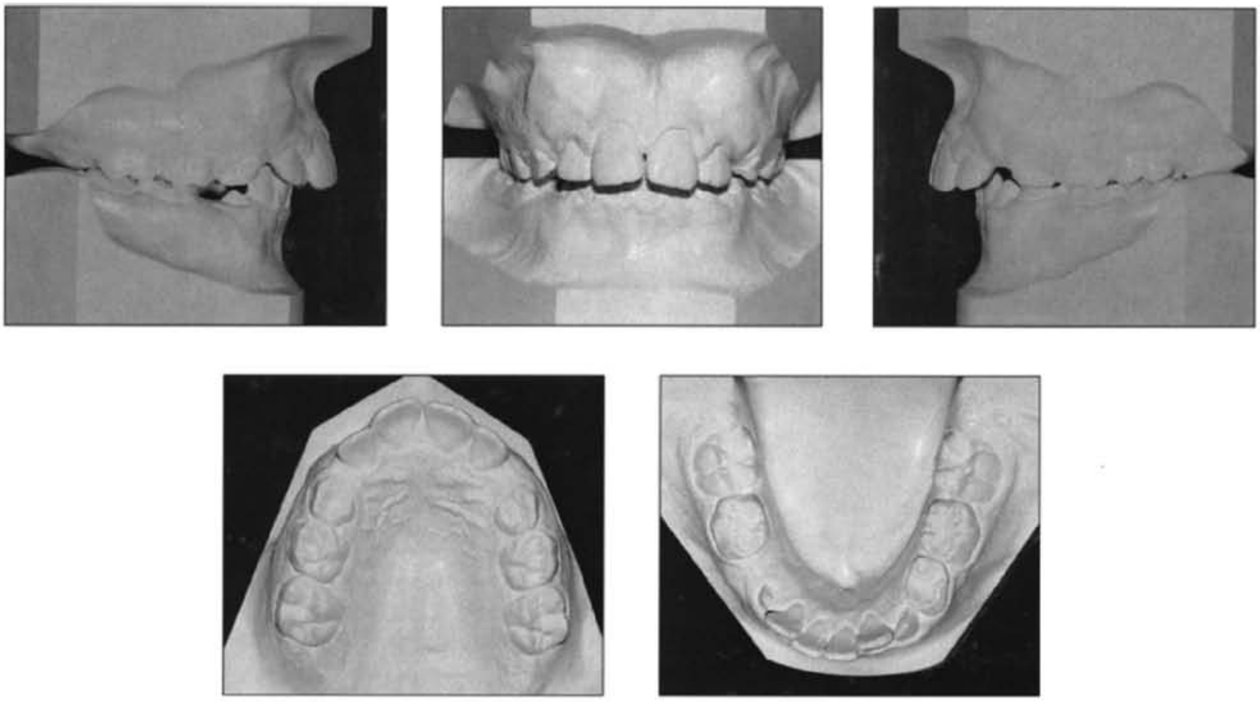

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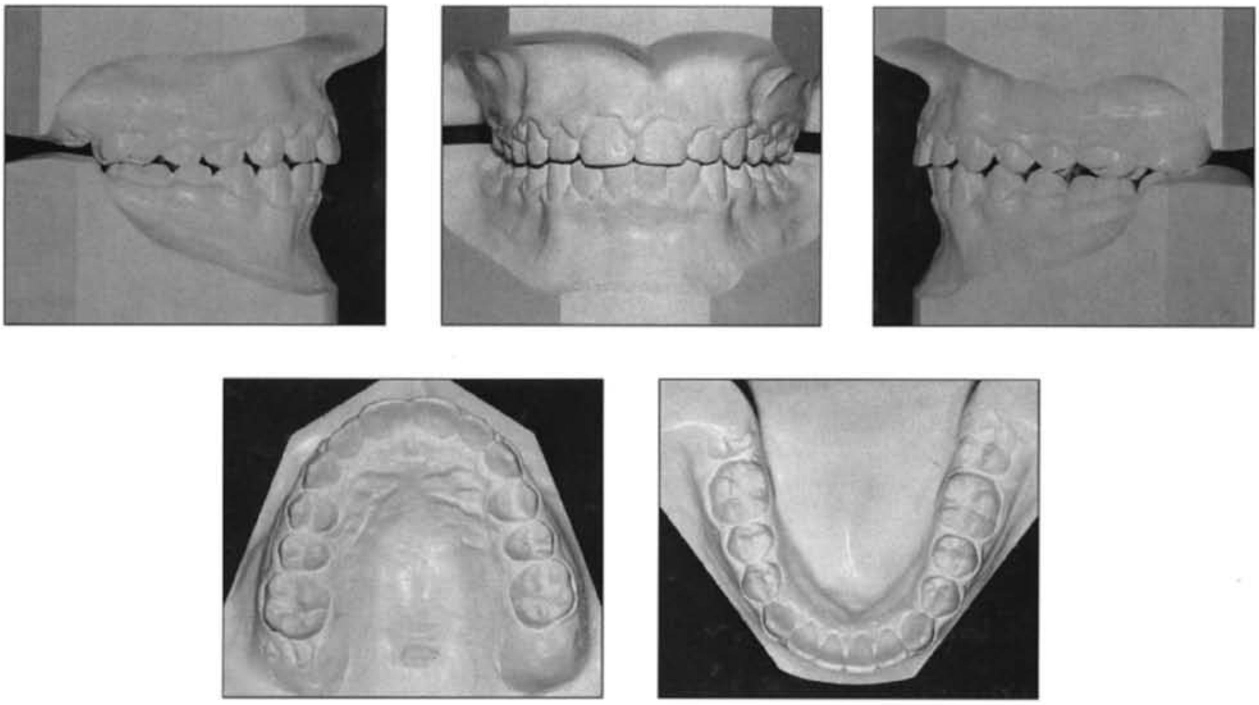

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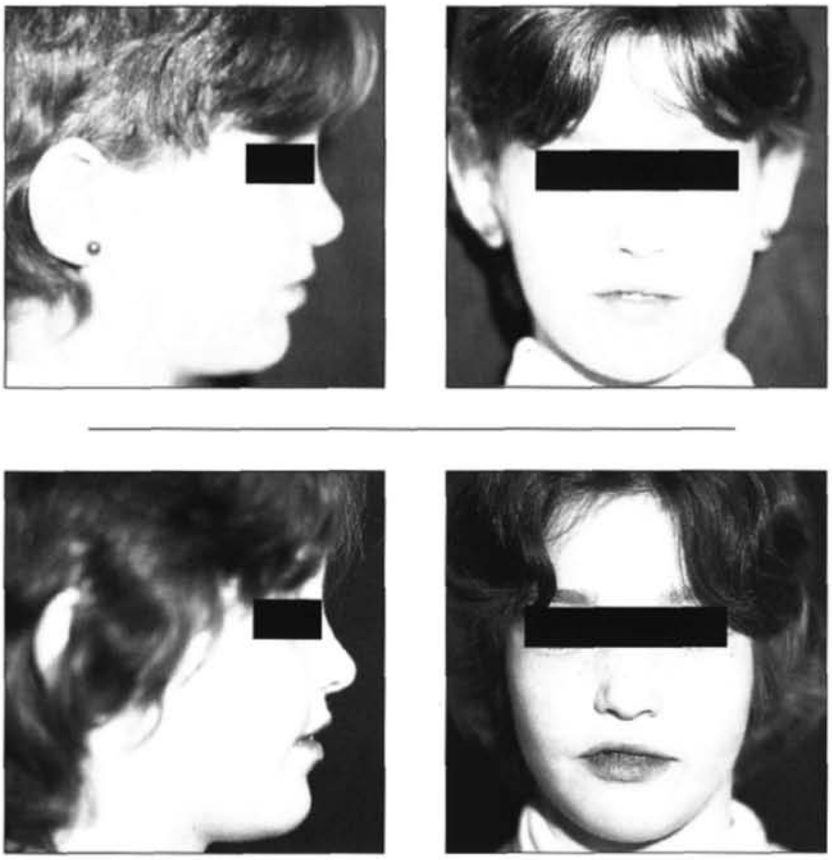
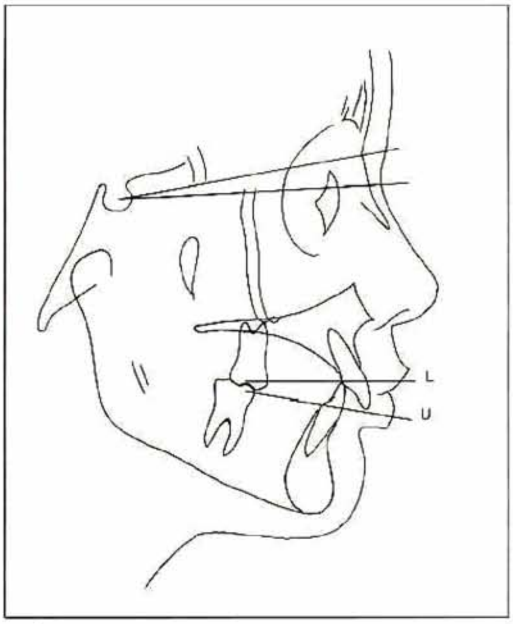


Patient KS has a Class II malocclusion and a deep overbite (Fig 3-19). The upper and lower natural planes of occlusion are not parallel (Fig 3-20a). Since too much of the upper incisor is displayed, the objective was to treat to the flatter, lower plane of occlusion (Fig 3-20b). This treatment involved intrusion and reorientation of the roots of the upper posterior teeth (a flattened plane moves the roots distally), which, while making treatment more difficult, enhanced stability by distalizing the roots more than the crowns. In this sense, flattening the occlusal plane is another method of overtreating a Class II patient. The final result approximates the treatment goals of incisor intrusion and flattening of the occlusal plane (Fig 3-20c).

Goal-oriented treatment requires that the final plane of occlusion must not be left to the vagaries of treatment mechanics. Therapy should be tailored to meet the goal of a desirable treatment plane of occlusion. Growth following treatment can, in some patients, correct errors in occlusal plane cant and level. On the other hand, an excessively steepened plane in a Class II malocclusion or an excessively flattened plane in a Class III malocclusion, if they rebound back toward the natural occlusal plane, can lead to instability. Also, Class II elastics or other mechanics often produce excessively toothy or gummy smiles, a condition that is not self-correcting with growth.

Fig 3-20 Patient KS. a, Before-treatment tracing showing diverging upper and lower natural planes of occlusion. b, Treatment-planning tracing (treatment objectives). Black, before treatment. Blue, 2-year growth. Red, planned tooth position. c, Before-treatment and after-treatment (green) tracings superposed. The upper incisors have been intruded and the occlusal plane flattened.



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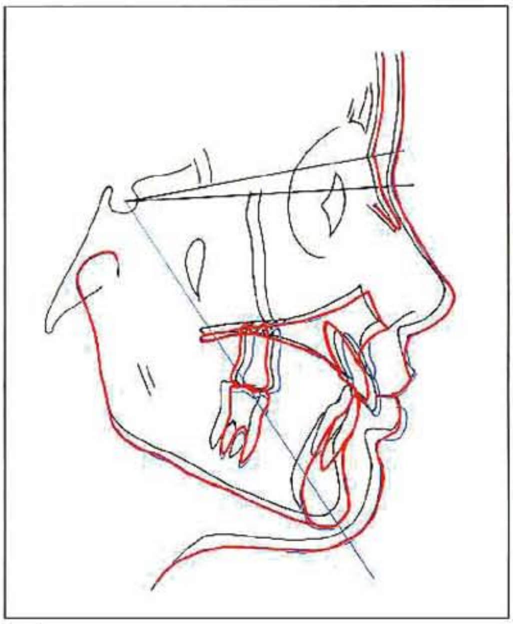

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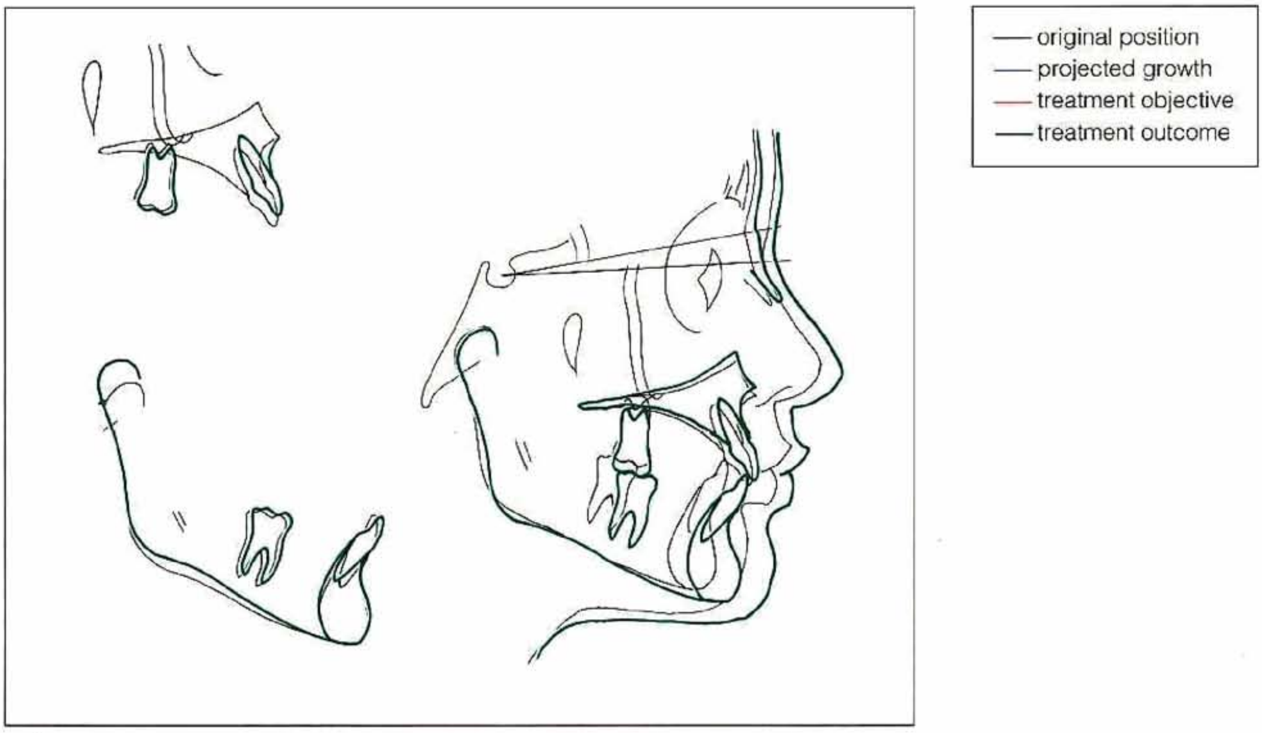

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4

Chapter

Arch Form and Dimension: Posterior Widths

One of the most important factors in treatment planning is the establishment of arch form. A full consideration of arch form requires determination of both the posterior arch widths and the anteroposterior position of the incisors.

Early in the history of orthodontics, around the time of Edward Angle, one of the goals of treatment was to achieve normal or average arch widths. Thus, very narrow arches were expanded to produce broader or more typical arch widths, and guides such as the Bonwill-Hawley diagram or the Pont index were used to set the standards for proper arch form and dimension. Although it may be possible to modify arch form in some patients, today it is known that only a limited amount of posterior width change is possible, and change in the region of the canines is particularly limited.

Nonetheless, there are a number of reasons why one might consider changing the posterior widths: (1) to create additional space in the arch; (2) to coordinate the widths of the upper and lower arches as part of the treatment for a crossbite; (3) to improve the buccolingual axial inclinations; and (4) to improve the esthetics (although this may only be appreciated by the orthodontist whose treatment goal is to produce a predetermined, idealized arch form).

Perhaps the most important factor to consider when determining posterior arch widths is whether the arch width will be stable.

Determining Stability of Arch Widths

The simple model in Fig 4-1 shows a band of muscle facial to the teeth: it begins at the orbicularis oris complex, continues into the buccinator, and finally joins the superior constrictor of the pharynx. Lingually lies the tongue. Between the tongue and this perioral musculature, there is no balance of forces. During swallowing, for example, tongue pressures are considerably greater than those exerted by the cheeks and lips. How is it possible, then, for the teeth to be in equilibrium? A working hypothesis is that, when they are expanded into the cheek, the teeth have relatively constant forces exerted on them. However, if the teeth are positioned lingually, the tongue may be in a position to move out of the way, particularly in an anteroposterior direction. Even though tongue forces are greater than buccal forces during swallowing, the buccal forces operate constantly throughout the day, and they may

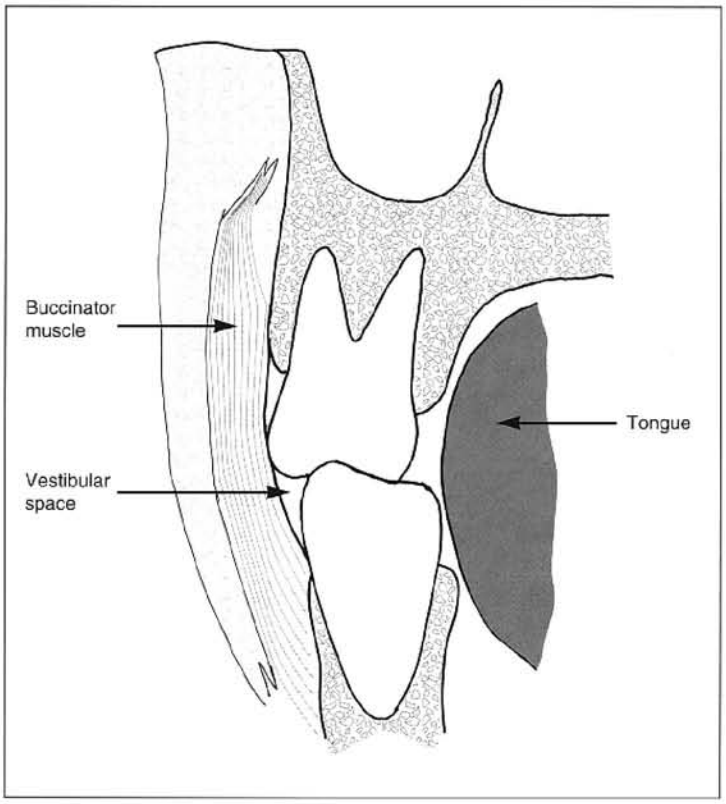


Fig 4-1 Equilibrium between cheek and tongue does not exist at any given point in time. Tongue forces during swallowing are greater than cheek forces, but cheek forces act more constantly. The vestibular space facial to the lower molar allows for minimal contact between the cheek and the upper molar.

be the limiting factor in how far teeth can be positioned buccally. In addition to muscle forces from the cheeks and tongue, occlusal forces also help to maintain equilibrium. Our working model of dental equilibrium is therefore a dynamic one: throughout the day, posterior teeth may be moving buccally during swallowing, but the forces of the cheeks return them to a more lingual position; occlusal forces also produce buccolingual movements. What we call a "stable position," then, is nothing more than a "mean position" of the teeth over a 24-hour period. At any given moment, all of the forces acting on the teeth do not sum to zero force, and hence, equilibrium does not exist.

Someday, sophisticated strain gauges and computers will allow orthodontists to determine the balance of forces operating in the mouth. Until that time, our approach to establishing potential stability is somewhat elementary. One guide is the soft tissue drape of the cheek and lip area relative to the buccal surfaces of the posterior teeth.

Normally, when the cheek contacts the upper molar, a small space can be seen between the buccal surface of the lower molar and the cheek (Fig 4-1). This space, known as the lower vestibular space, is caused by the normal buccal overjet in the posterior region. When a patient opens his mouth slightly past the rest position, one can easily observe the relationship of the cheek to the facial surfaces of the lower teeth. Typically, the cheek contacts the lower canines in the area of the middle to incisal one third of the crown; in the first molar region, the cheek contacts the buccal surface at the gingival one third of the crown, allowing sufficient vestibular space so that the upper posterior teeth do not press into the cheek.

Although the tongue is an adaptable part of the muscle system, the degree to which it can change its position and form is limited if the teeth are moved lingually. Therefore the lingual musculature must be evaluated in terms of the relative tongue size and posture and such functions as swallowing and speech.

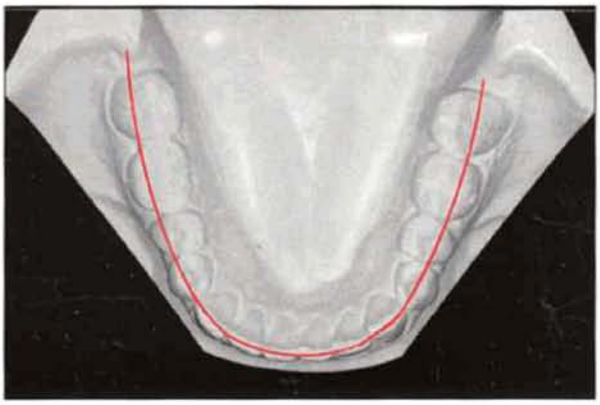


Fig 4-2 Typical human arch. From canine to canine a smooth curvature is formed, which is not necessarily a segment of a circle. Premolars diverge toward the distal. A change in direction at the first molar is produced by curvature in the buccinator muscle as it attaches to the pterygomandibular raphe. Considerable variation in arch forms and dimensions can be observed in both treated and untreated patients.

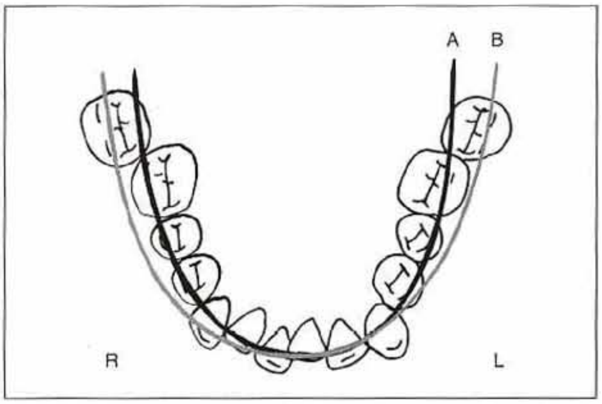


Fig 4-3 A mean position of the teeth does not establish arch form. Second molars are blocked to the buccal into the cheek. Canines have erupted buccally. A, Correct and potentially stable arch form. B, Arch form based on mean tooth position is too wide.

The stable human arch varies considerably in form, width, and symmetry. It is helpful to describe the arch as a series of lines or curves connecting the incisal edges and the tips of the buccal cusps. Typically the curvature that is observed from canine to canine is not necessarily a segment of a circle (Fig 4-2). From the tip of the canine posteriorly to the mesiobuccal cusp of the first molar, a diverging straight line (curve) is found. At the first molar the buccal line changes direction, diverging less than the canine segment. This change of direction, which can be directly observed intraorally, is influenced by the buccinator–superior constrictor musculature, and it serves as a useful guide to arch form. The buccal line is variable and should be altered if posterior teeth are moved either anteriorly or posteriorly.

It has often been said that the existing width may be the most stable, since the teeth have been subjected to functional forces that have determined their present positions. However, treatment to eliminate a crossbite, new occlusal forces, or the retraction of anterior teeth can cause conditions to change, which could reduce pressures in the corner of the mouth. To establish the arch form, some orthodontists average the means of the contact areas; this may be erroneous, since some of the teeth could be correct and others can be "out of line." Using the cheek as a guide enables one to distinguish those teeth that are normally positioned from those that are malpositioned.

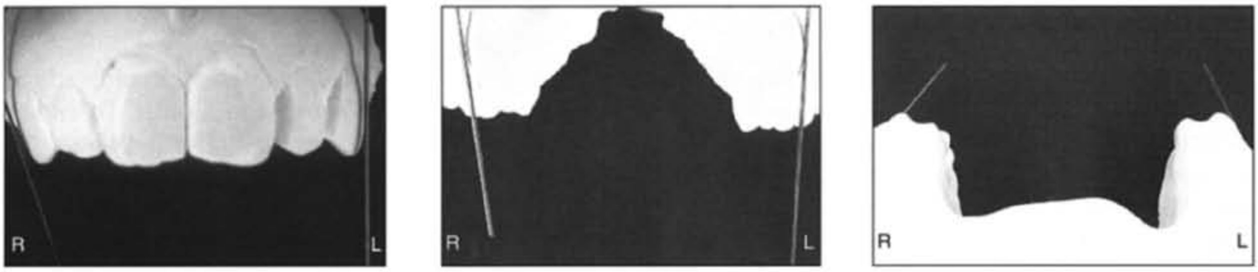
For example, in the lower arch shown in Fig 4-3, the second molars and canines have erupted into the cheek. Based on a good premolar–first molar relationship to the cheek, the correct arch form is (A). If the arch form were based on a mean of the contact areas (B), the posterior teeth would be positioned too far buccally.

Orthodontists spend a good deal of time fabricating symmetrical arch wires for their patients, but the dental arch is often asymmetrical. One reason for the asymmetry is a difference between the maxilla and the mandible in bone width between the right and left sides. Mandibular asymmetry caused by greater unilateral growth also results in arch width asymmetry.

Fig 4-4 Patient with a mandibular asymmetry with dental compensations. a, The right side is Class III, the left side is Class II, and the lower midline is to the left of the upper midline. b, The upper left canine is more labially inclined than the upper right canine. The upper left first molar is more buccally inclined than the upper right first molar, and the lower left first molar is more lingually inclined than the lower right first molar. c, Relative to the median palatal plane, the upper arch is wider on the left side and the lower arch is wider on the right side. d, The posteroanterior headfilm tracing shows the asymmetrical buccolingual axial inclinations of the canines, which compensate for the skeletal discrepancy (the mandible is positioned to the left). The difference in axial inclinations is increased if measured to the interpupillary line rather than to the occlusal plane.

a

b



The patient shown in Fig 4-4 has a marked skeletal asymmetry with a Class III relationship on the right and a Class II relationship on the left. With an asymmetry of this type one would expect to find a large crossbite on the patient's left side, since growth has shifted the mandible to the left; however, very little crossbite is seen, even in the cast sections (Fig 4-4b). In the upper arch, the left molar and canine are visibly leaning buccally more than the right molar and canine. In the lower arch, the left first molar leans lingually more than the right first molar. The occlusal view reveals different widths relative to the median palatal raphe (Fig 4-4c). Because of these compensations in axial inclinations, the posterior teeth on the left side have a larger width in the upper arch and a smaller width in the lower arch. Compensations in axial inclinations are also seen on the tracing of the posteroanterior headfilm (Fig 4-4d). To treat this asymmetry, this patient requires orthognathic surgery. The axial inclinations are then made

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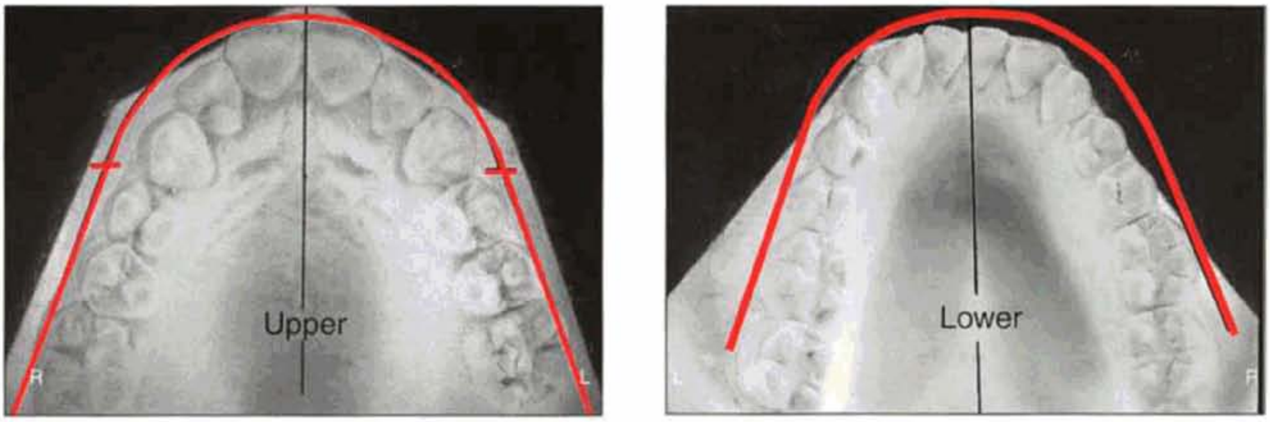

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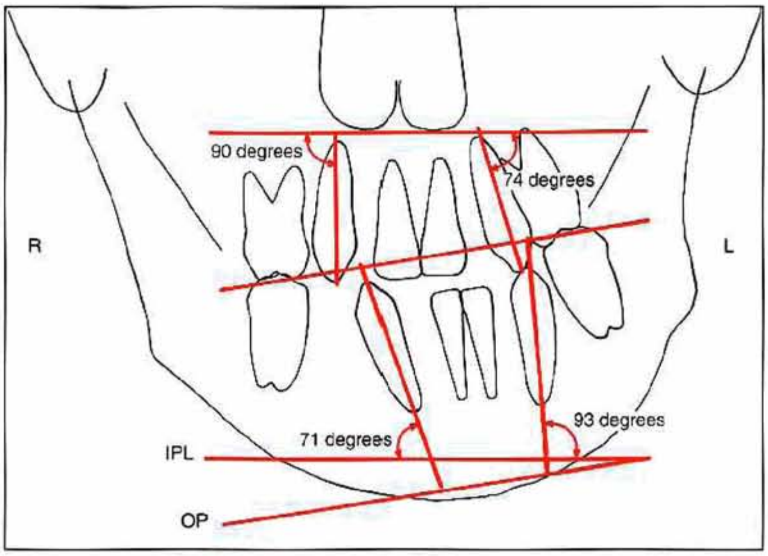

symmetrical during the orthodontic phase of treatment. In patients with mild skeletal asymmetries not requiring orthognathic surgery, it is sometimes necessary to maintain these compensations in axial inclinations. Attempts to correct them by means of tooth movement would result in crossbites or would cause root tips to be positioned through the buccal or lingual plates of bone. Often, then, these mild, nonsurgical, transverse skeletal asymmetries require different buccolingual axial inclinations on the right and left sides and are of different widths on the right and left sides relative to the median palatal raphe; hence, the ideal arch wires for these patients would be asymmetrical.

Buccolingual axial inclinations often deviate from the norm; those that improve the occlusion are termed convergent axial inclinations, whereas those that produce or exacerbate an occlusal problem are said to have divergent axial inclinations. Not all patients with skeletal discrepancies show dental compensations such as in Fig 4-4; because of occlusal forces, some show an exaggerated, unilateral, or bilateral crossbite.

Fig 4-5 A skeletal bilateral crossbite with a narrow upper basal width. a, Before-treatment study casts. b, Sections cut through the mesial surfaces of the first molars show relatively normal buccolingual axial inclinations with some compensation (convergence). c, Posteroanterior headfilm tracing shows that uprighting the molars would worsen the crossbite.

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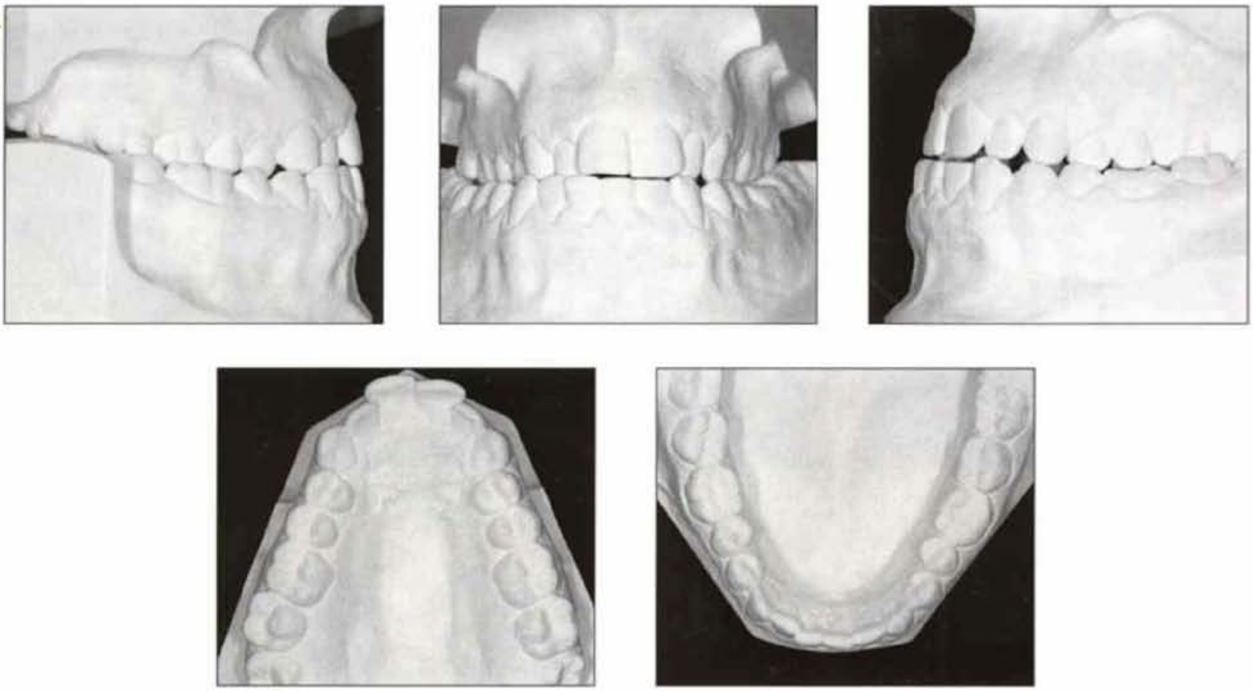


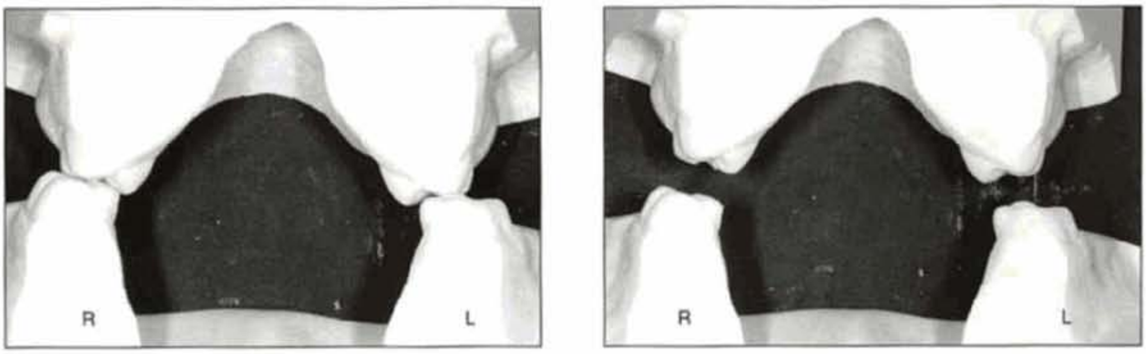
Distinguishing Dental from Skeletal Crossbites

Treating a patient with a posterior crossbite involves making a decision about which posterior teeth—upper or lower or both—should be repositioned. The starting point for such an evaluation requires the mandible to be in centric relation rather than centric occlusion position. Dental study casts also should be trimmed to the centric relation position, and sometimes a centric wax bite is needed for the posteroanterior films in order to position the patient in centric relation during the exposure. In the presence of a unilateral crossbite, mandibular shifts can give the illusion of an asymmetry; thus, jaw registrations should always be made in the nonshift, centric relation position.

It may be helpful to evaluate the width of the basal bone of the maxilla relative to that of the mandible, based on the clinical exam, casts, and headfilms; however, this is never simple, and the results will not be exact. Determining whether buccolingual axial inclinations are normal, convergent, or divergent is a simple and clinically useful method for distinguishing dental from skeletal crossbites.

The patient in Fig 4-5 exhibits a bilateral crossbite. The basal maxillary arch is narrow relative to a wide basal mandible. At rest, the tongue assumes a low position within the mandibular arch. The cast section made through the mesial surfaces of the first molars shows a relatively normal buccolingual axial inclination with some tendency for convergence or compensation (Fig 4-5b). Uprighting the molars mentally would

b



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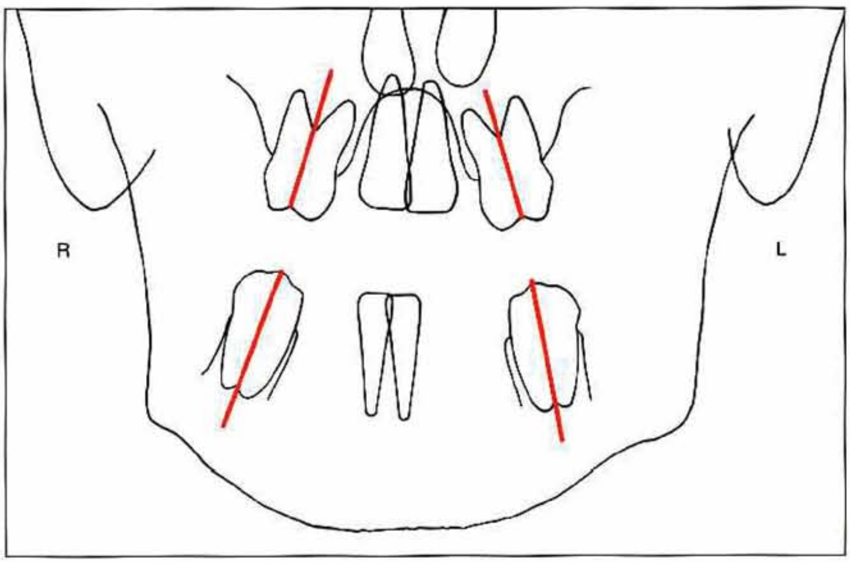
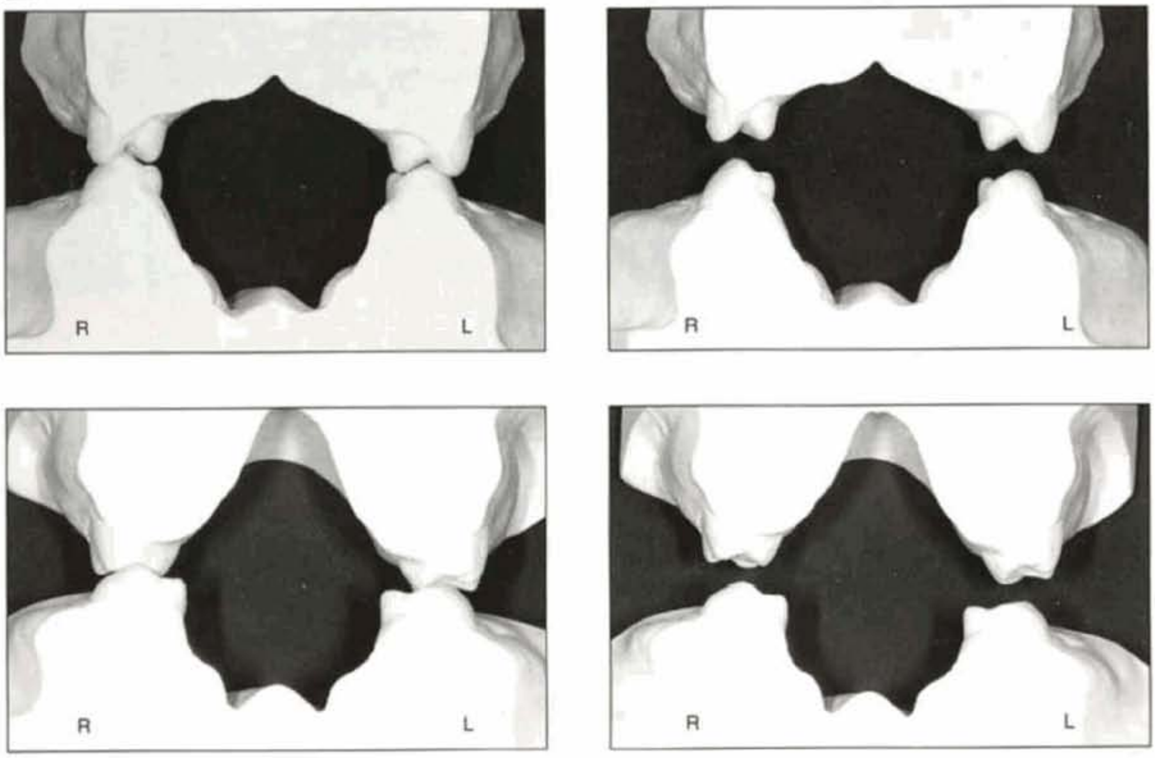


exacerbate the crossbite. The posteroanterior tracing confirms the cast findings, showing some compensations in axial inclination (Fig 4-5c). A diagnosis of skeletal crossbite can be made based on the axial inclinations of the molars.

The patient shown in Fig 4-6 is similar to the one in Fig 4-5 in that both have a wide basal mandible opposed by a narrow maxilla; however, in this patient no crossbite exists. The posterior axial inclination convergence has compensated for the skeletal discrepancy, most notably in the mandible. More inclination or convergence is found on the patient's right side, suggesting a greater maxillomandibular width discrepancy on that side when measured to the midpalatal raphe. Normalizing the axial inclinations by tipping around a point near the center of the root would produce a crossbite. A hidden crossbite such as this can become a genuine skeletal crossbite if the treatment mechanics eliminate these compensations. Mechanics that are designed to correct the axial inclinations by moving the upper roots buccally or the lower roots lingually are also futile since anatomic limitations would cause the root tips to perforate the alveolar processes.

Fig 4-6 Skeletal discrepancy in width between basal maxilla and mandible. a, Sections cut through the mesial surfaces of the premolars and molars show a convergence of the axial inclinations; note that the right molars lean lingually more than the left molars, suggestive of a skeletal arch width asymmetry. b, Posteroanterior headfilm tracing shows that the upper molars are in buccoversion, while the lower molars are in linguoversion. This is an example of a "hidden crossbite," since uprighting the molars would result in a crossbite.

a



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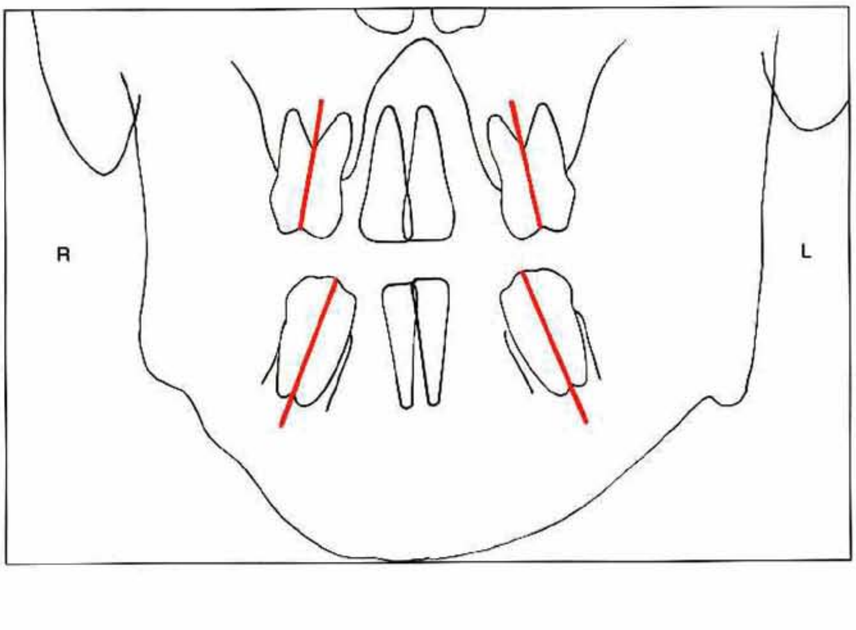
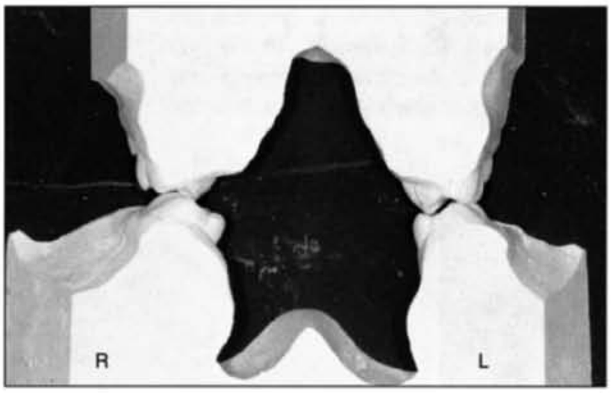




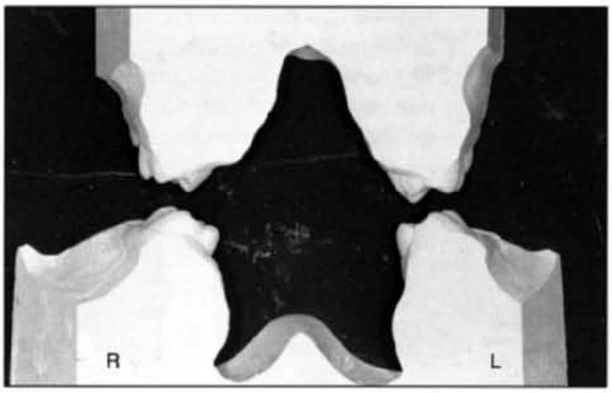


Fig 4-7 Narrow maxilla with wide mandible. Teeth have compensated for the width discrepancy. In nonsurgical treatment, the patient is treated to these abnormal axial inclinations.

Another hidden skeletal crossbite is shown in Fig 4-7. Uprighting the upper and lower molars mentally produces a bilateral crossbite. Note that the right side exhibits more axial inclination convergence; hence, the crossbite would be much greater on the right.

The principle of using tooth inclinations as diagnostic guides can also be used to identify dental crossbites. In dental crossbites, the inclinations are divergent; therefore, normalization of these axial inclinations eliminates or replaces the crossbite. Typically, dental crossbites are more localized, usually involving only a few teeth or arch segments rather than an entire arch.

The patient in Fig 4-8 shows an arch length inadequacy with a crossbite of the left first molars. The buccolingual axial inclinations of the upper first molars are similar (Fig 4-8b), while those of the lower first molars are not, with the left one leaning to the buccal. Uprighting the left molar reduces the crossbite. The axial inclination is divergent; therefore, the crossbite is mainly dental. The cast section through the second molars shows no crossbite (Fig 4-8c). Here, one can observe nature's solution to harmonizing the upper and lower widths. Unlike the first molars, the lower second molars lean lingually. Note the difference in axial inclination between the right and left sides: the lower left first molar has greater linguoversion than the lower right, suggesting a small skeletal basis for the unilateral crossbite. The goal of treatment is to reproduce in the first molars the stable axial inclinations of the second molars. The occlusal view gives an inaccurate impression; if a mean of the contact areas were used to establish arch form, the second molar on the left would appear too far to the lingual. If bilateral maxillary expansion were planned, the lower second molar widths could be wider; however, some difference between the right and left sides is required.

Figure 4-9 shows a Class I malocclusion with a unilateral crossbite on the right side. Looking at the occlusal view of the casts, an arch form based on the mean or average of the contact areas would suggest that the lower right second molar is too far to the lingual. However, the cast sections demonstrate that this conclusion would be faulty (Fig 4-9b). A divergent inclination is found on the lower right first molar (Fig 4-9b); when partially corrected, the crossbite is reduced. Second molars show convergent axial inclinations, with the lower right leaning slightly more to the lingual than normal (Fig 4-9c). In this patient the diagnosis of a dental crossbite is based in part on the position of the second molars, which serve as a guide to posterior arch widths. The inclinations of the second molars are slightly convergent, implying a small skeletal maxillomandibular width discrepancy.

Fig 4-8 Dental crossbite of the left first molars. a, Before-treatment study casts. b, Sections cut through the mesial surfaces of the first molars. The lower left first molar is inclined buccally. Uprighting it would result in a crossbite. c, Sections cut through the mesial surfaces of the second molars. No crossbite is found. Nature's solution is a lingually inclined lower left second molar.

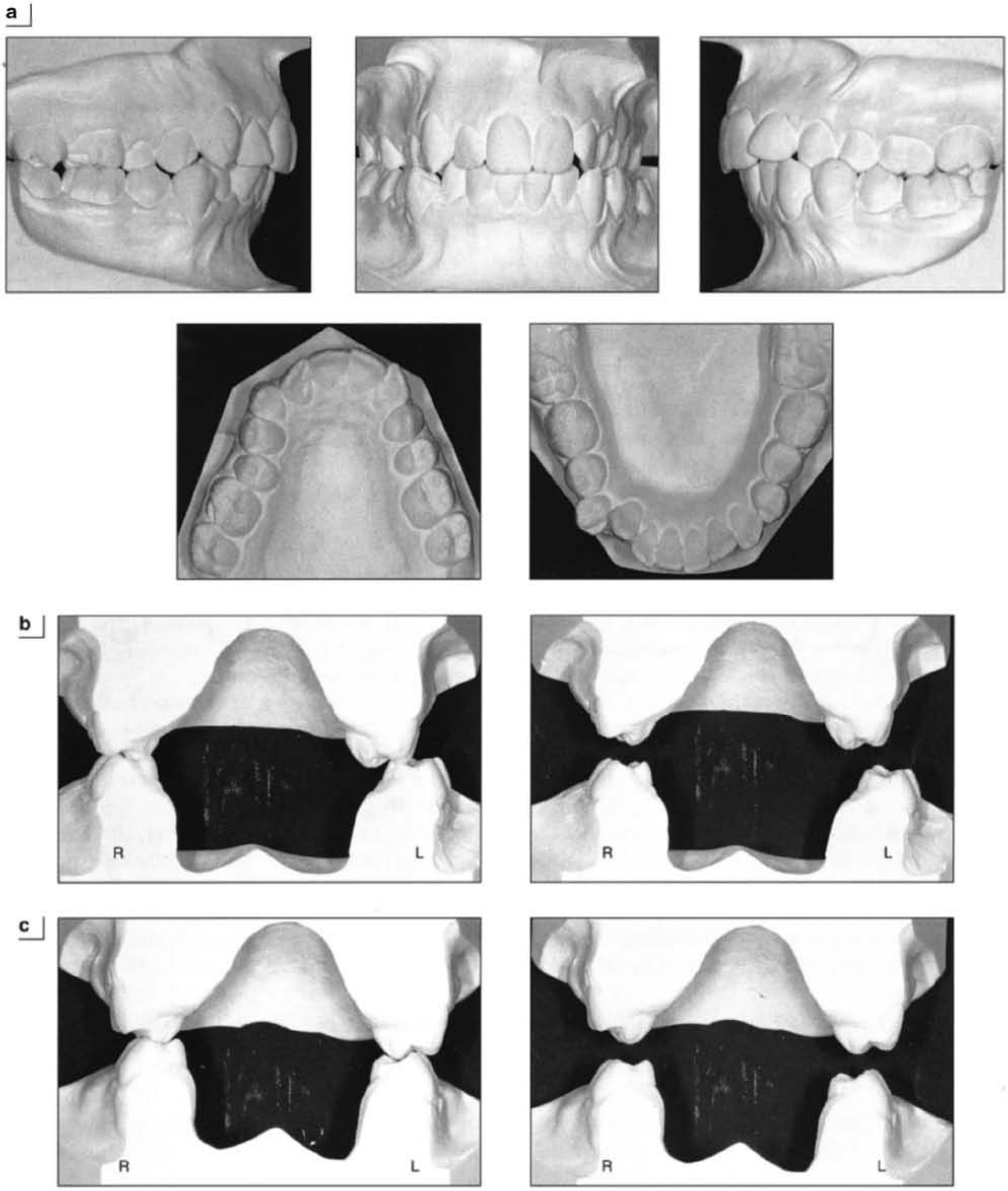
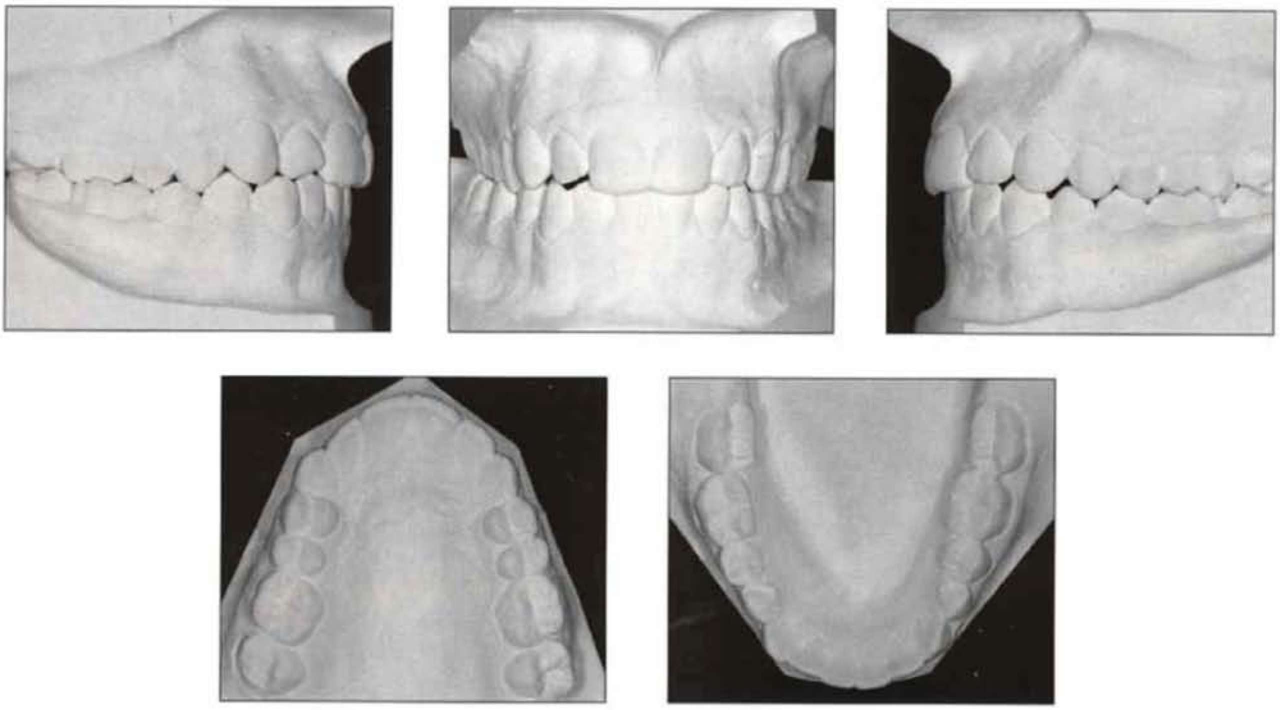


Fig 4-9 Unilateral dental crossbite. a, Before-treatment study casts: lower right second molar appears to be positioned too far lingually. b, Sections cut through the mesial surfaces of the first molars. The upper right molar is lingual and the lower right molar is buccal, leading to a dental crossbite. c, Sections cut through the mesial surfaces of the second molars. Note compensations in the right second molar, where no crossbite is found; hence, this tooth is not positioned too far lingually.

a



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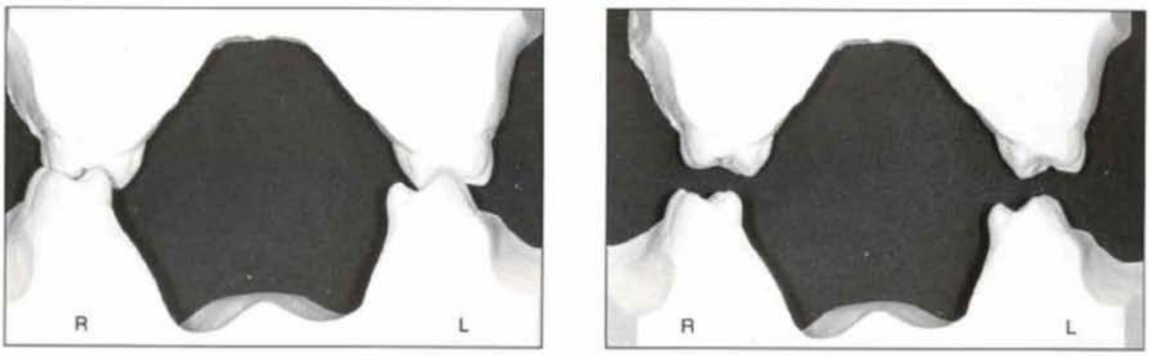

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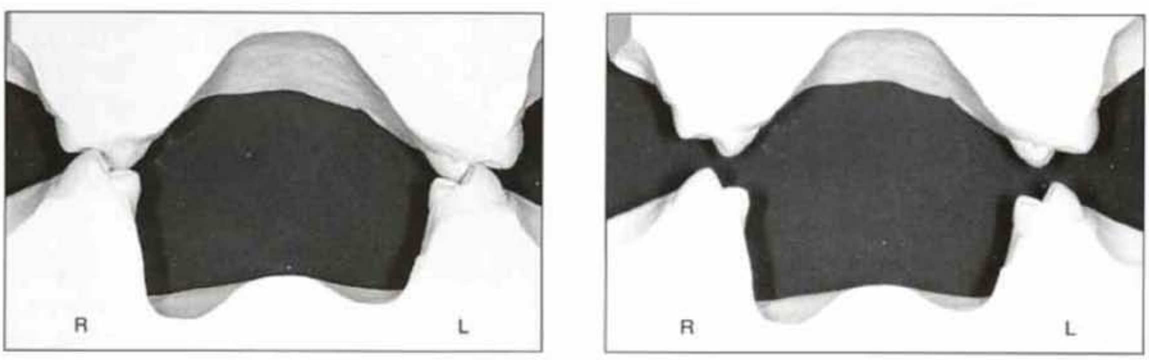
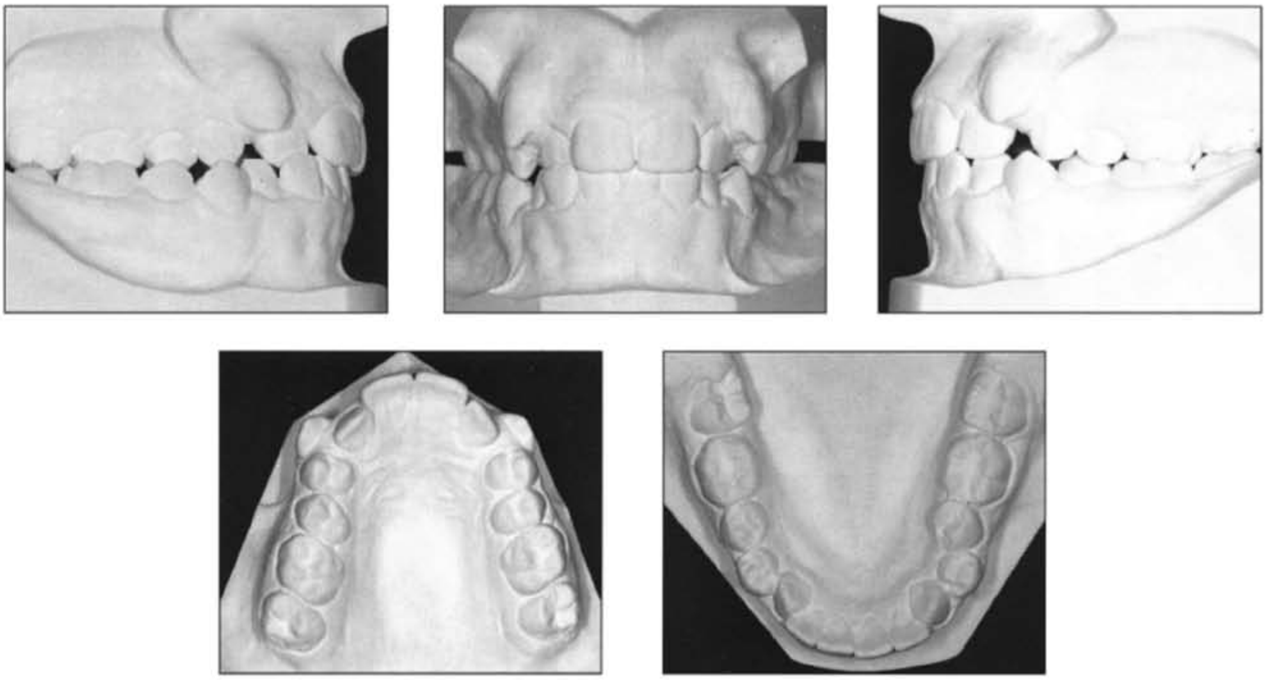


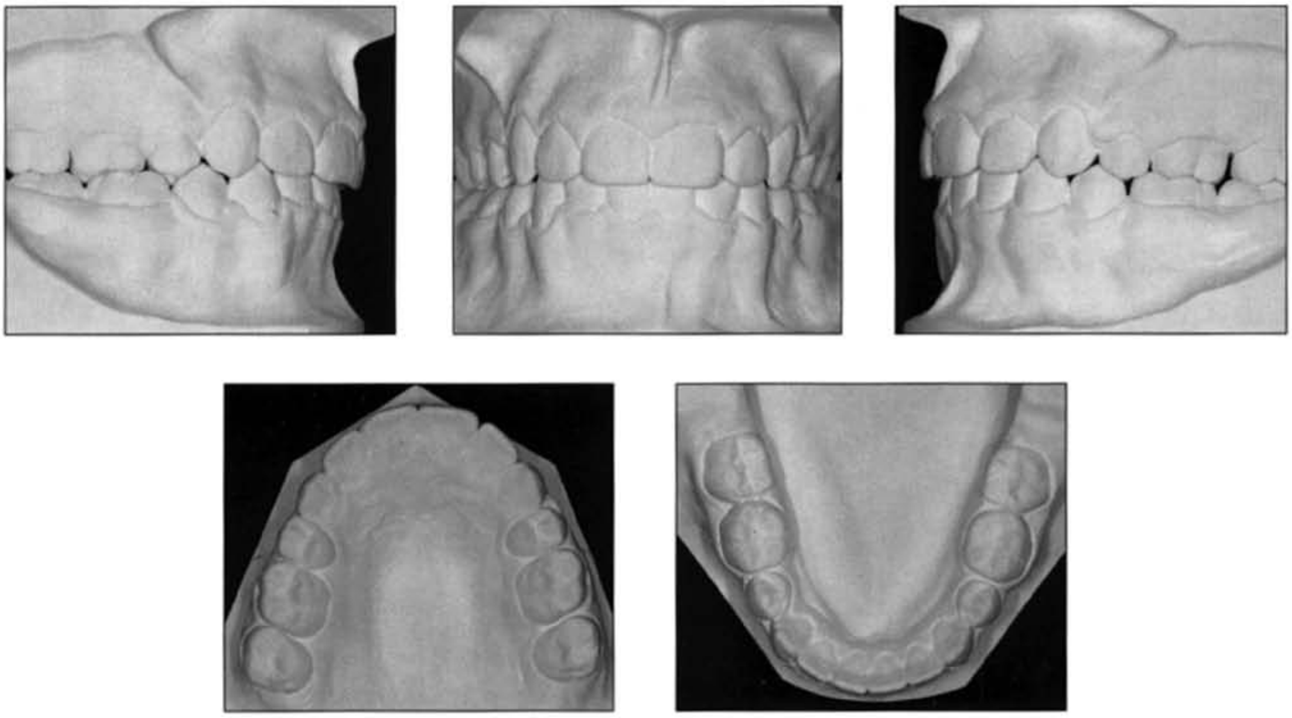
Fig 4-10 Unilateral Class II malocclusion with crossbite on the right side. a, Before-treatment study casts. b, After-treatment study casts. c, Sections cut through the mesial surfaces of the premolars before and after treatment. Upper right premolars have been tipped buccally and the lower right premolars tipped lingually. d, Sections cut through the mesial surfaces of the first molars before and after treatment. The upper right first molar has been tipped buccally and the lower right first molar has been tipped lingually. e, Sections cut through the mesial surfaces of the second molars before and after treatment. The axial inclinations of the second molars have been maintained during treatment. f, Superposed cephalometric tracings: black, before treatment; green, after treatment; red, treatment objective. g, Differences in buccolingual axial inclinations on the right and left sides confirm a diagnosis of dental crossbite. h, Occlusogram: original malocclusion (black) shows desired arch form and width (red). i, Occlusogram showing changes after treatment. The final tooth position approaches the treatment objectives: black, before treatment; green, after treatment.

a



The patient in Fig 4-10 exhibits an arch length inadequacy and a unilateral Class II molar occlusion and crossbite on the right side. Treatment required extraction of the upper first and lower second premolars (Figs 4-10a and 4-10b), and asymmetrical mechanics were used to resolve the unilateral crossbite and Class II relationship. Cast sections made through the mesial surfaces of each of the posterior teeth are shown before and after treatment (Figs 4-10c to 4-10e). Initially, in the region of the premolar and first molar, there was little difference in axial inclination between the right and left sides. The crossbite was corrected by producing convergent axial inclinations, primarily in the upper arch; that is, the upper second premolar and first molar were tipped to the buccal. Note that the second molars had the same compensating axial inclinations prior to treatment that were placed in the first and second premolars at the end of treatment. As shown in other patients, second molars can sometimes be helpful in determining widths

b



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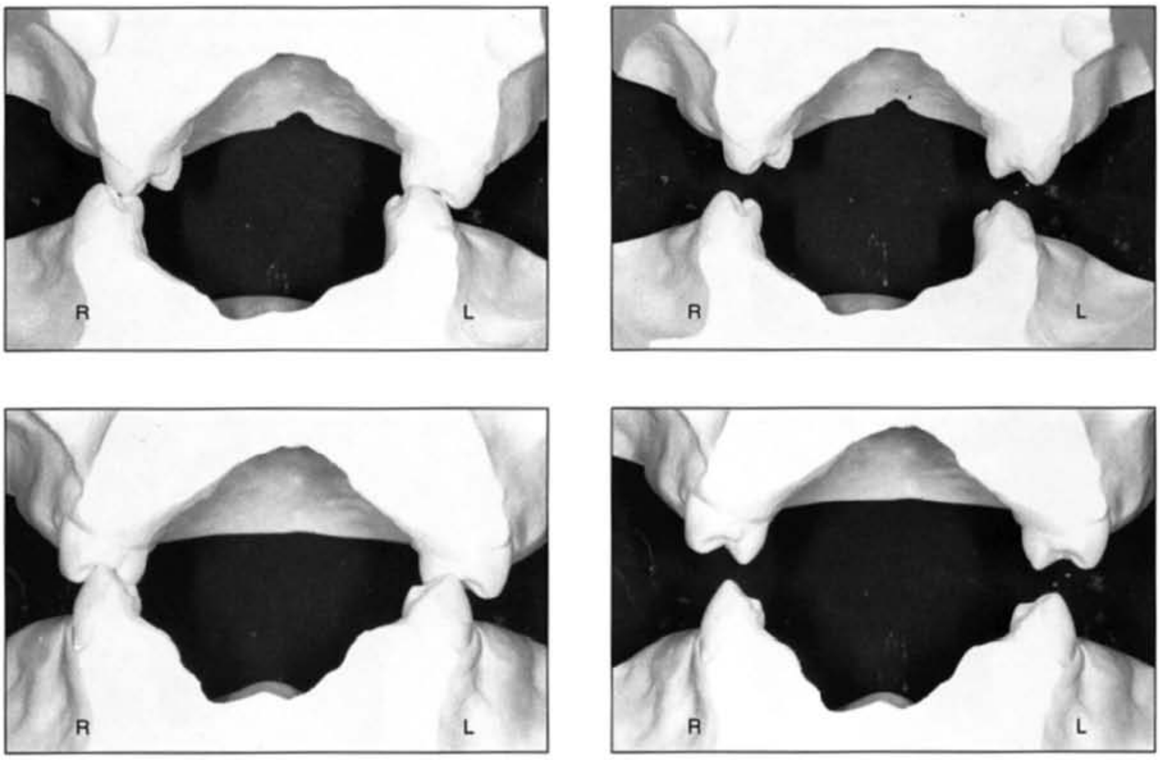

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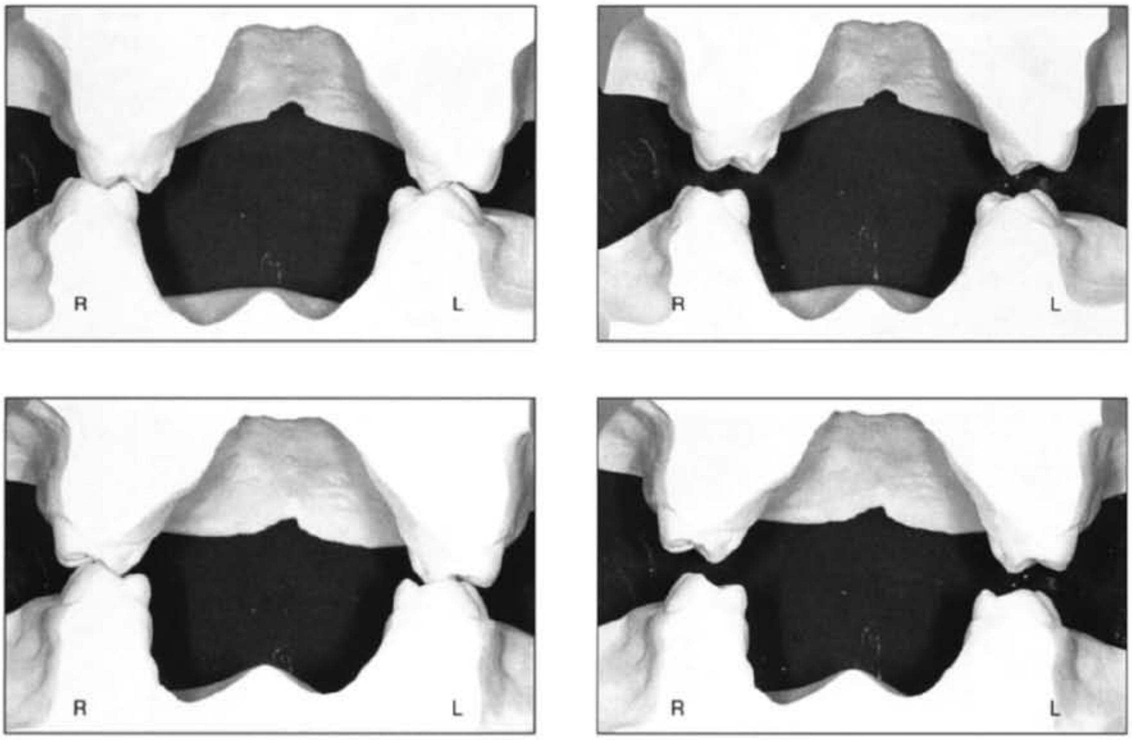

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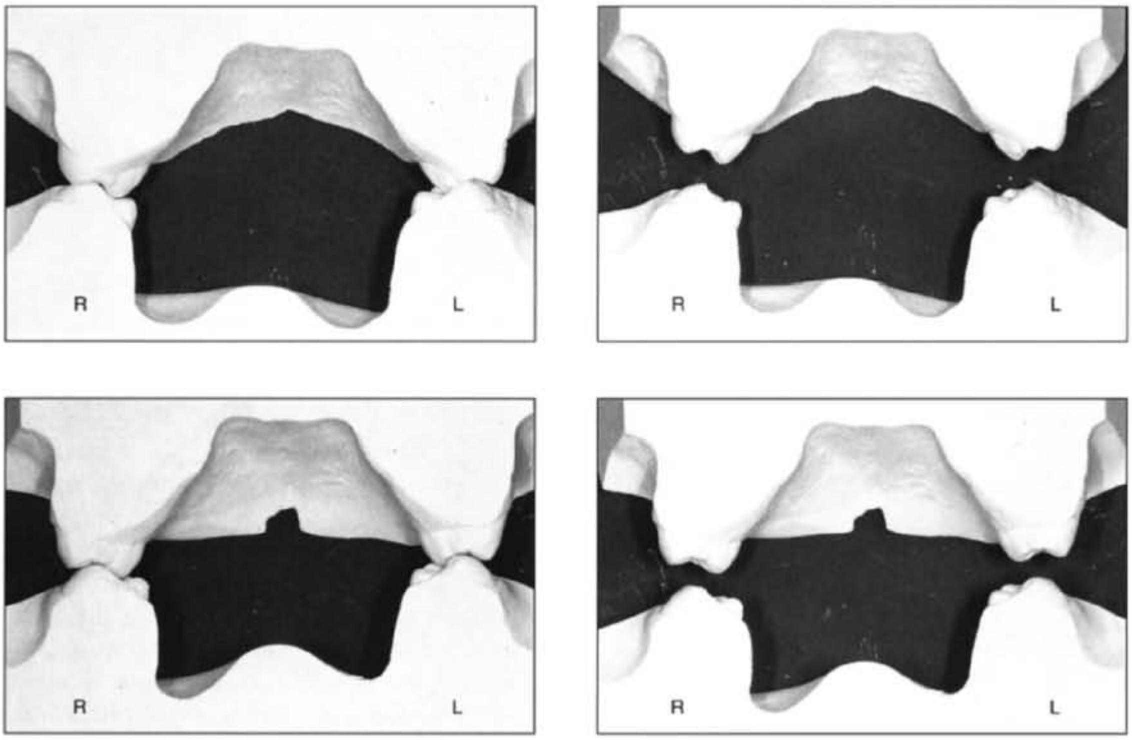

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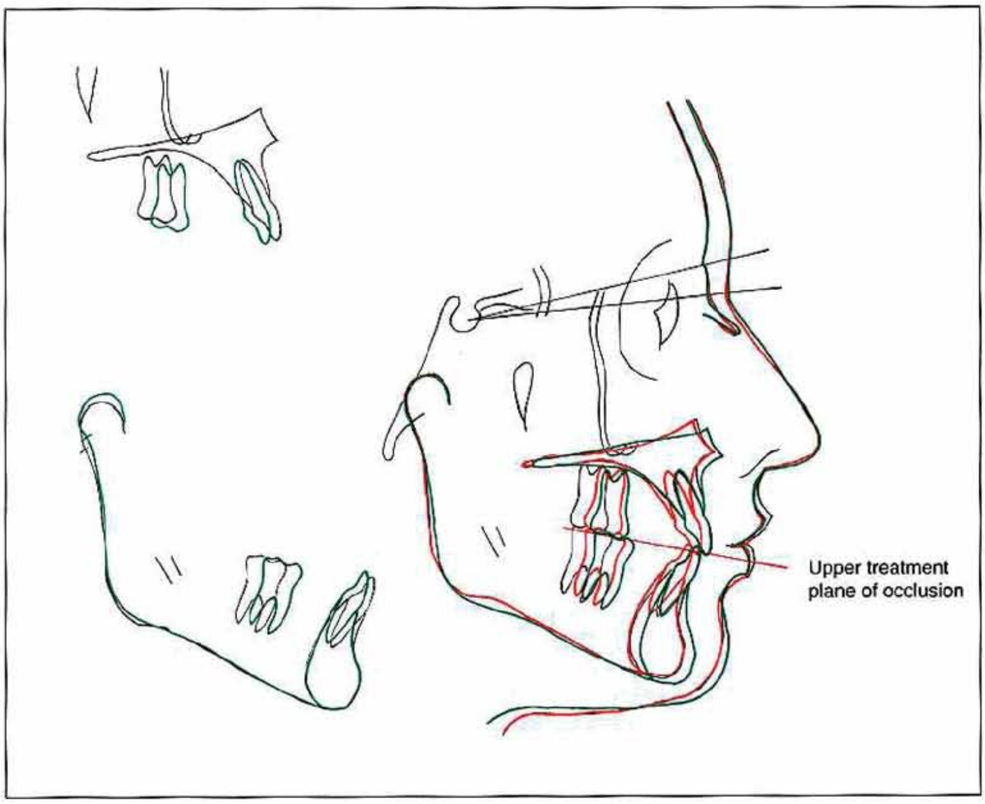

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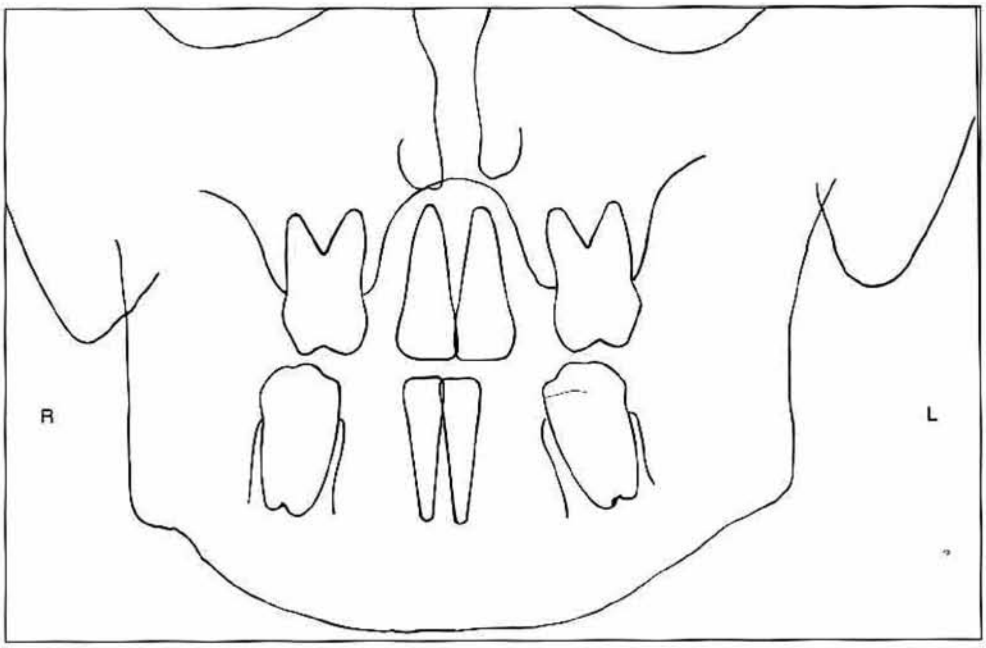
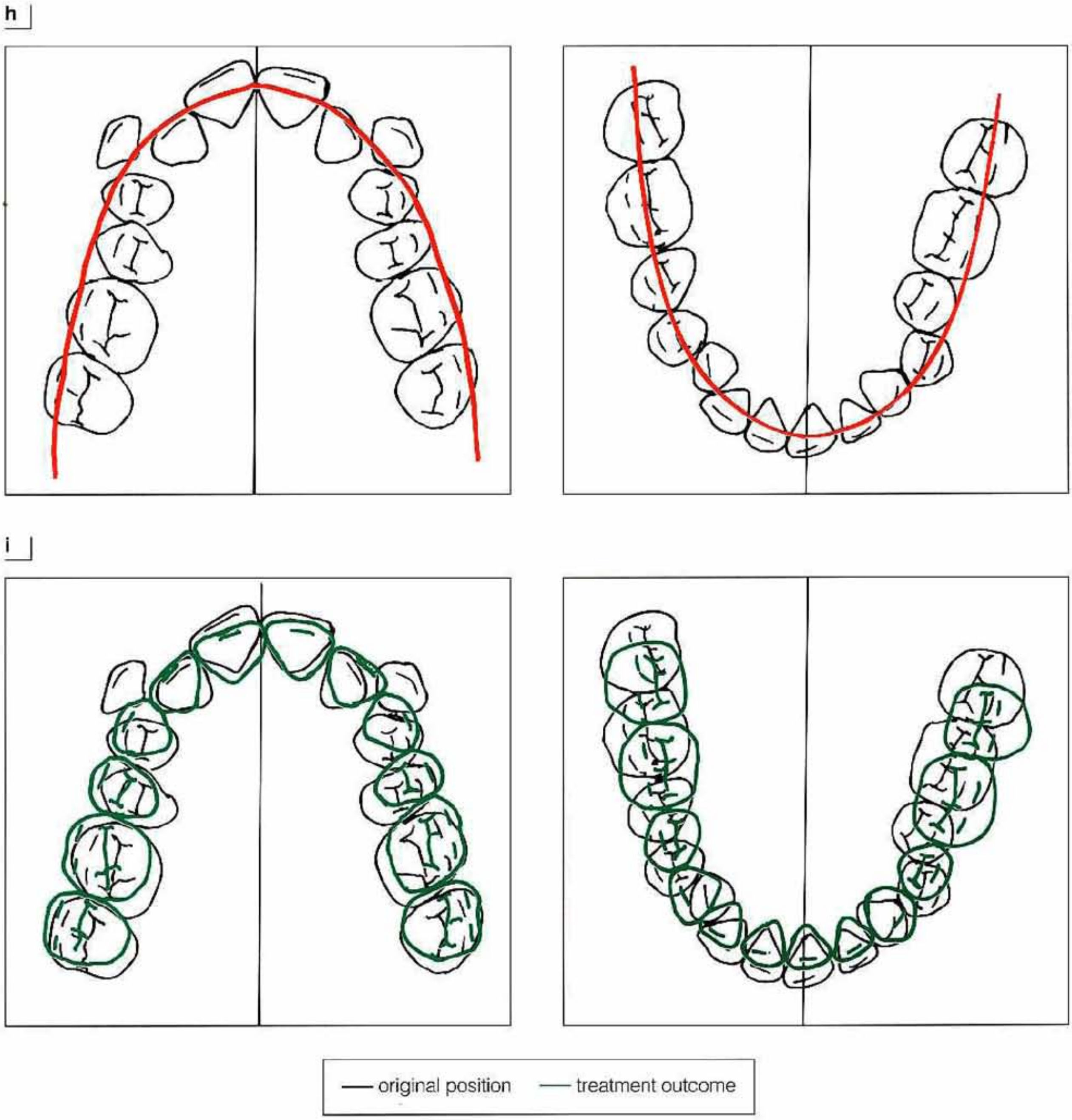


— original position — treatment objective — treatment outcome

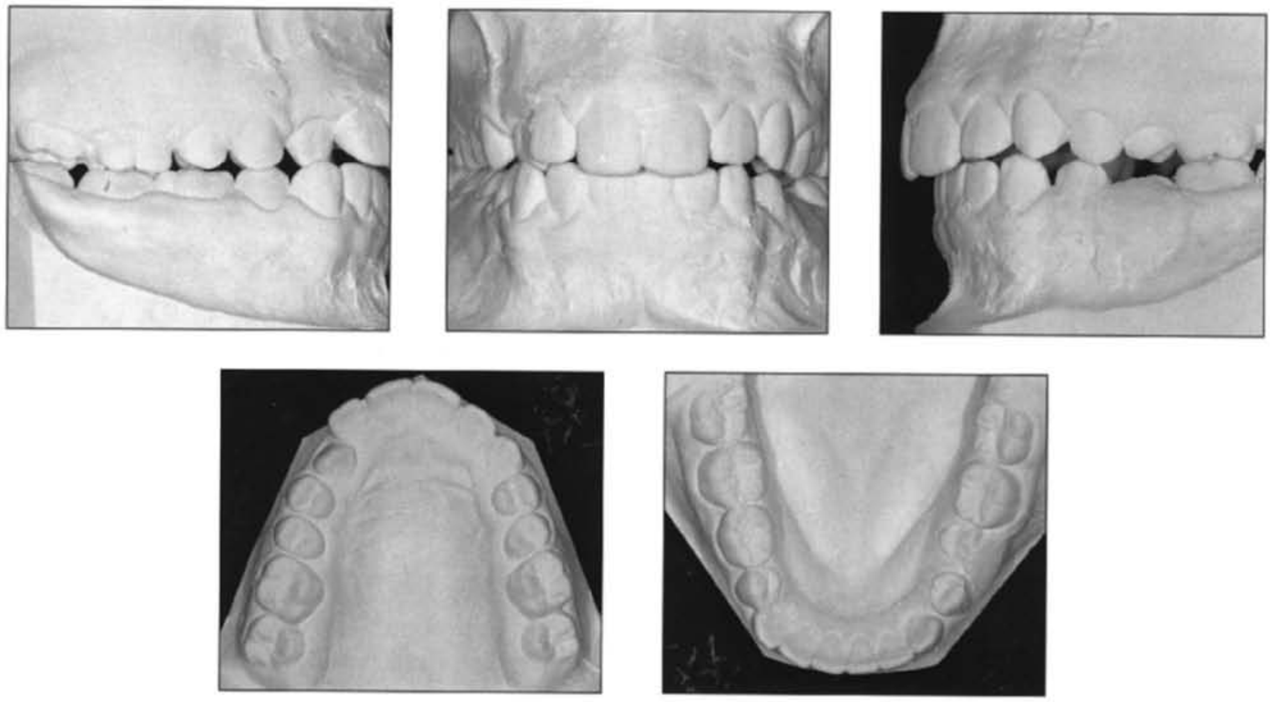


at the posterior of the arch. Obviously, blocked-out or malposed second molars cannot be used as a guide. The posteroanterior tracing confirms what is illustrated by the cast sections; that is, the posterior axial inclinations are relatively symmetrical and the unilateral crossbite is skeletal in nature (Fig 4-10g). The desired arch form and arch widths are drawn on the occlusogram (Fig 4-10h); the before and after occlusogram superpositions show that the planned arch form and arch widths closely correspond to the achieved results (Fig 4-10i).

Figure 4-11a shows a simple dental crossbite. The upper right canine leans lingually; the lower right canine leans labially in contrast to the normal left side (Fig 4-11b). Only simple tipping is required to correct the divergent axial inclination of this localized problem.

Fig 4-11 Localized dental crossbite of the upper right canine. a, Before-treatment study casts. b, Sections cut through the mesial surfaces of the canines show the upper right canine leaning lingually. Only simple tipping is required for its correction.

a



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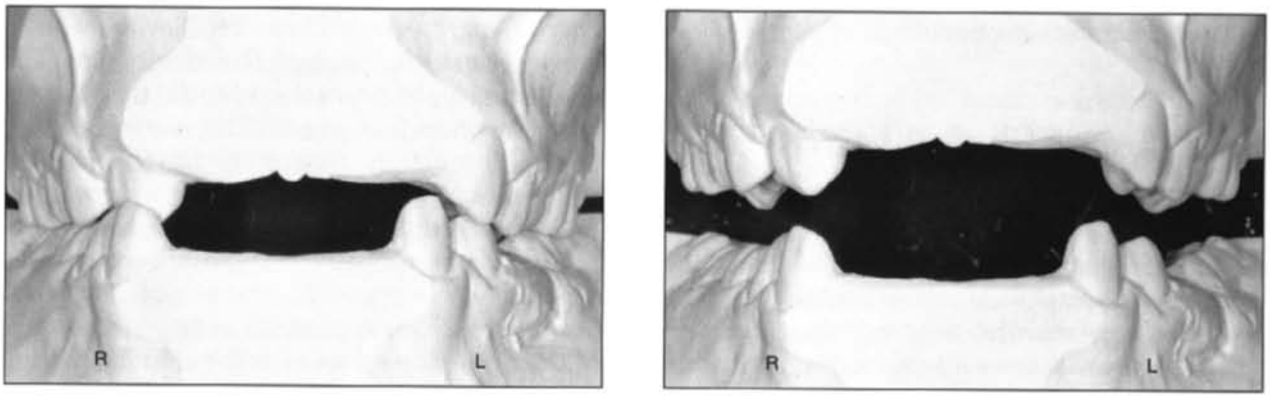
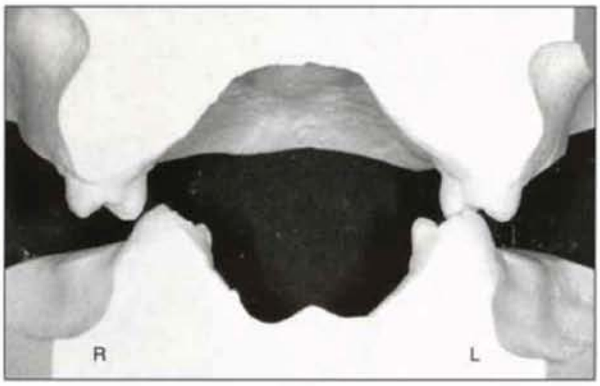




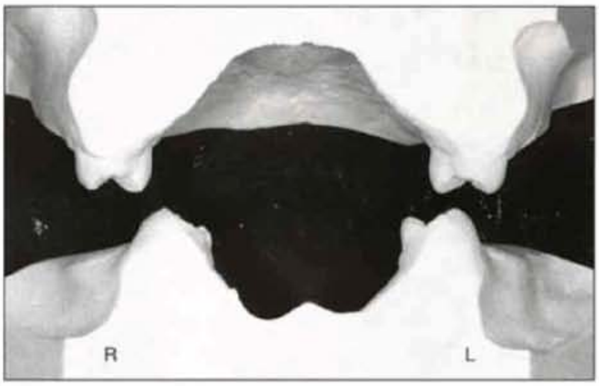


Fig 4-12 "Scissors bite": the upper right premolar is buccal to the lower. The problem tooth is the lower right premolar, which is in linguoversion.

Less common is the crossbite in which the upper teeth lie buccal to the lower teeth. In Fig 4-12, the upper premolars have relatively symmetrical axial inclinations (the upper right side is tipped slightly more to the buccal). This crossbite is primarily a result of the lingually tipped lower right premolar. Tipping the lower right premolar buccally would lead to symmetrical axial inclinations and no crossbite.

Stability of Skeletal Crossbite Correction

In the preceding section, careful evaluation of the buccolingual axial inclinations was shown to be useful as a means of distinguishing dental from skeletal crossbites and of finding possible approaches for correction. Even with dental crossbites, normalization of axial inclinations may not always be the most stable solution, and abnormal convergent axial inclinations may certainly be desirable in skeletal crossbites. Stability of the correction is related to muscle forces, particularly from the cheek and tongue. A dental crossbite with lingual tipping of an upper molar is pictured in Fig 4-13. Note that the cheek is not in contact with the upper molar. The upper molar can be tipped buccally into the large vestibular space, and hence a stable correction can be anticipated.

Contrast that to the cheek-tooth relationship found in a skeletal crossbite (Fig 4-14). The cheek is in contact with the upper molar and is compressed by the lower molar. If not for the occlusal interlocking, one would expect the lower molar to move lingually as a result of pressure from the cheek. Unlike the dental crossbite, the skeletal crossbite offers limited possibilities for achieving a stable resolution. Tipping the lower molar lingually is an option; however, it may encroach on the tongue, leading to instability. Moreover, tipping of the upper and lower molars accentuates an already excessive curve of Monson. Translation of the molars is not feasible because of the thin bone buccally in the maxilla and lingually in the mandible. The best solution is to resolve the skeletal discrepancy, either by orthognathic surgery in the maxilla or mandible, or orthopedically by maxillary sutural expansion. Unfortunately, even with surgery there may be a high relapse tendency. Although not ideal, another possibility would be to maintain the existing crossbite rather than to invite relapse into an end-to-end relationship and poor intercuspation.

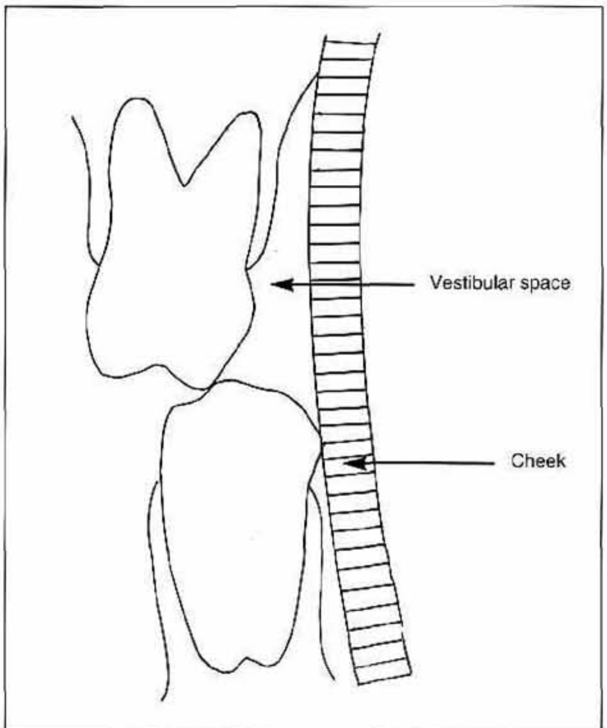


Fig 4-13 Soft tissue evaluation of crossbite correction. If the cheek is away from the upper molars, the molar can be stable when positioned buccally; this is characteristic of a dental crossbite.

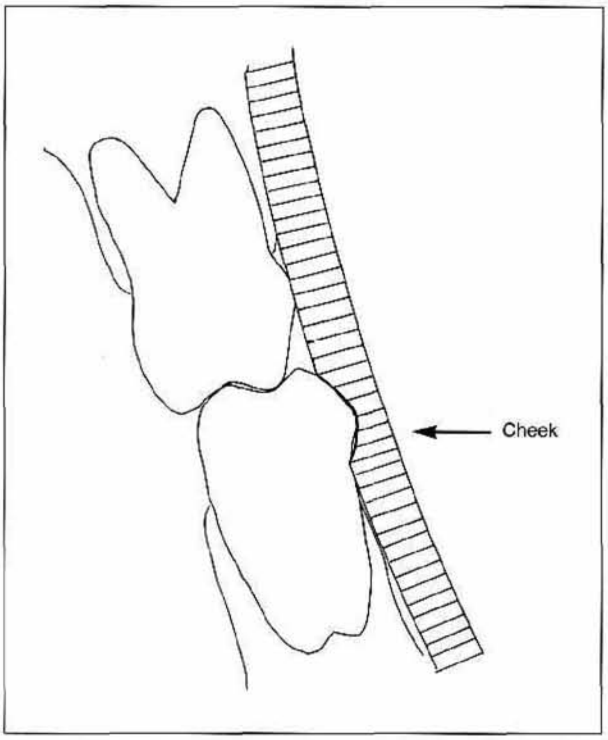


Fig 4-14 Soft tissue drape in a skeletal crossbite. The cheek touches the upper molar and the lower molar compresses the cheek; moving the upper molar buccally would not be a stable treatment option.

Pseudo-unilateral Crossbites

Some crossbites that appear to be unilateral may actually be bilateral in nature. The misdiagnosis is usually based on a faulty centric relation. The patient in Fig 4-15a has an apparent unilateral crossbite on the right side with a lower midline deviation. An end-to-end Class II molar relationship and open bite are also present. The open bite is associated with diverging occlusal planes and infraocclusion of the upper incisors. Marked protrusion of the upper and lower lips is evident. The treatment plan included extraction of the first premolars and retraction of the incisors. As is shown in the posttreatment cast and cephalometric tracings, the incisors were retracted, reducing the lip protrusion. The upper occlusal plane steepened and the lower occlusal plane flattened, closing the open bite (Figs 4-15b and 4-15e). In addition, incisors in infraocclusion to the occlusal plane were erupted. The steepening of the upper occlusal plane and eruption of the upper incisors improved the upper incisor–lip relationship.

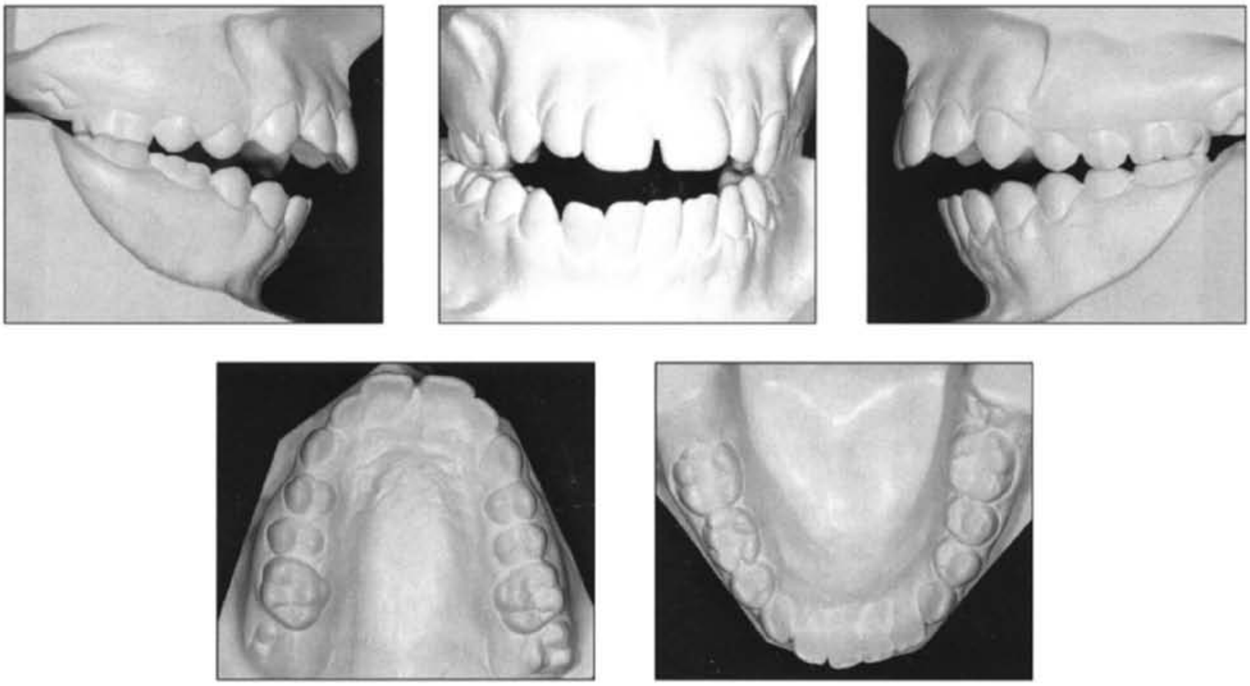
No asymmetrical mechanics were used to correct the crossbite. As the upper arch was widened, the mandible shifted to the left, correcting both the crossbite and the midline discrepancy. The original casts are shown in centric occlusion, which is diagnostically misleading in that it does not register the correct jaw relationship. It is important that centric relation be established to avoid an improper treatment plan using asymmetrical mechanics.

Two-year postretention casts are shown in Fig 4-15c. The crossbite correction is stable, although there is a slight open bite tendency and a small midline diastema between the upper incisors.

Since mandibular shifts are common in patients with unilateral crossbites, special care should be taken when registering the centric relation position of the jaws.

Fig 4-15 Class II malocclusion with an open bite. a, Before-treatment study casts. Pseudo-unilateral crossbite on the right side with diverging occlusal planes. b, After-treatment study casts. Treatment included extraction of the first premolars. c, Two-year postretention study casts. d, Before- and after-treatment facial photos showing a reduction in lip protrusion. e, Superposed cephalometric tracings: black, before treatment; red, after treatment; green, 2 years postretention. The upper occlusal plane has been steepened to close the open bite. Upper lip–incisor relationship has been improved. f, The occlusogram shows that the crossbite has mainly been corrected by a mandibular shift to the left in the correct "centric relation." No asymmetrical mechanics were required.

a



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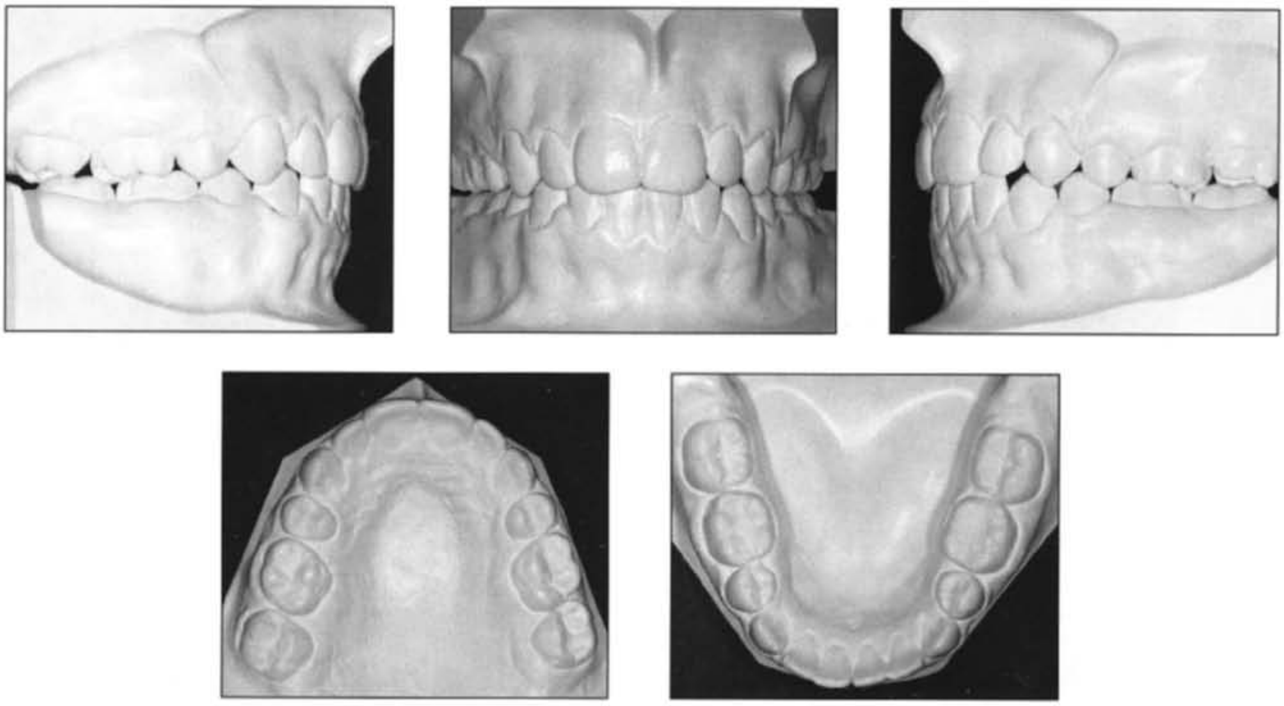

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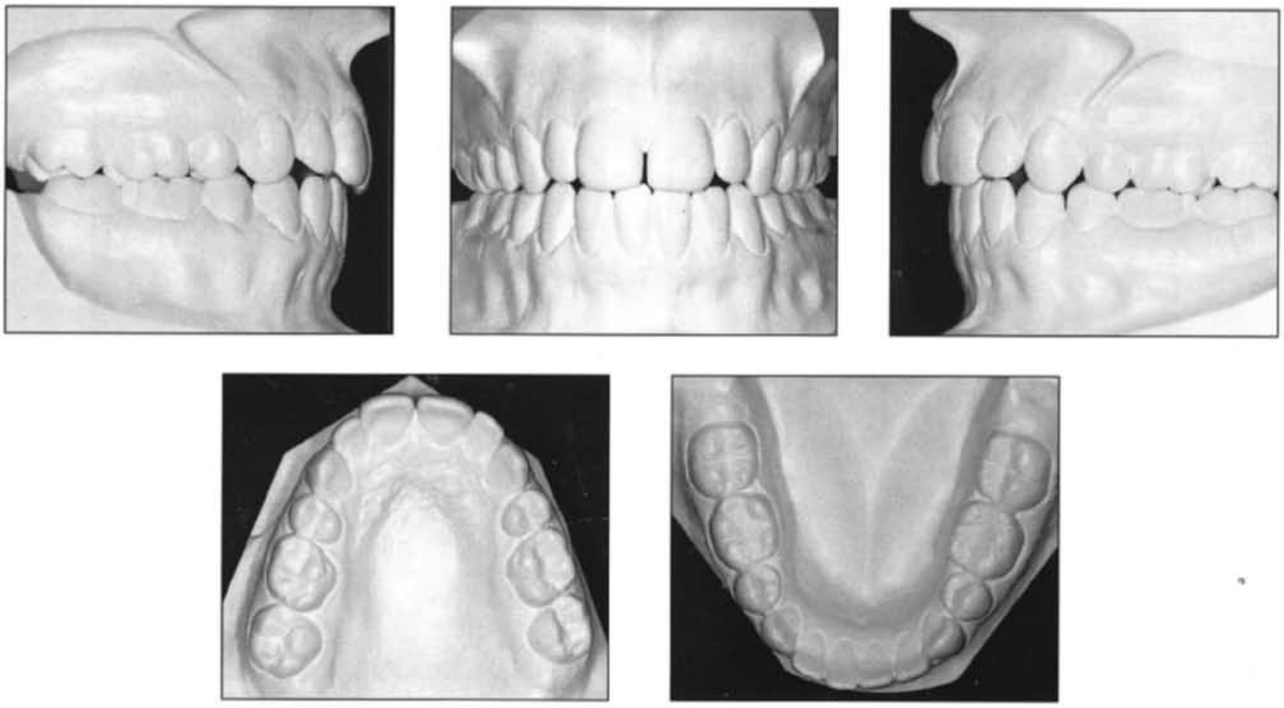

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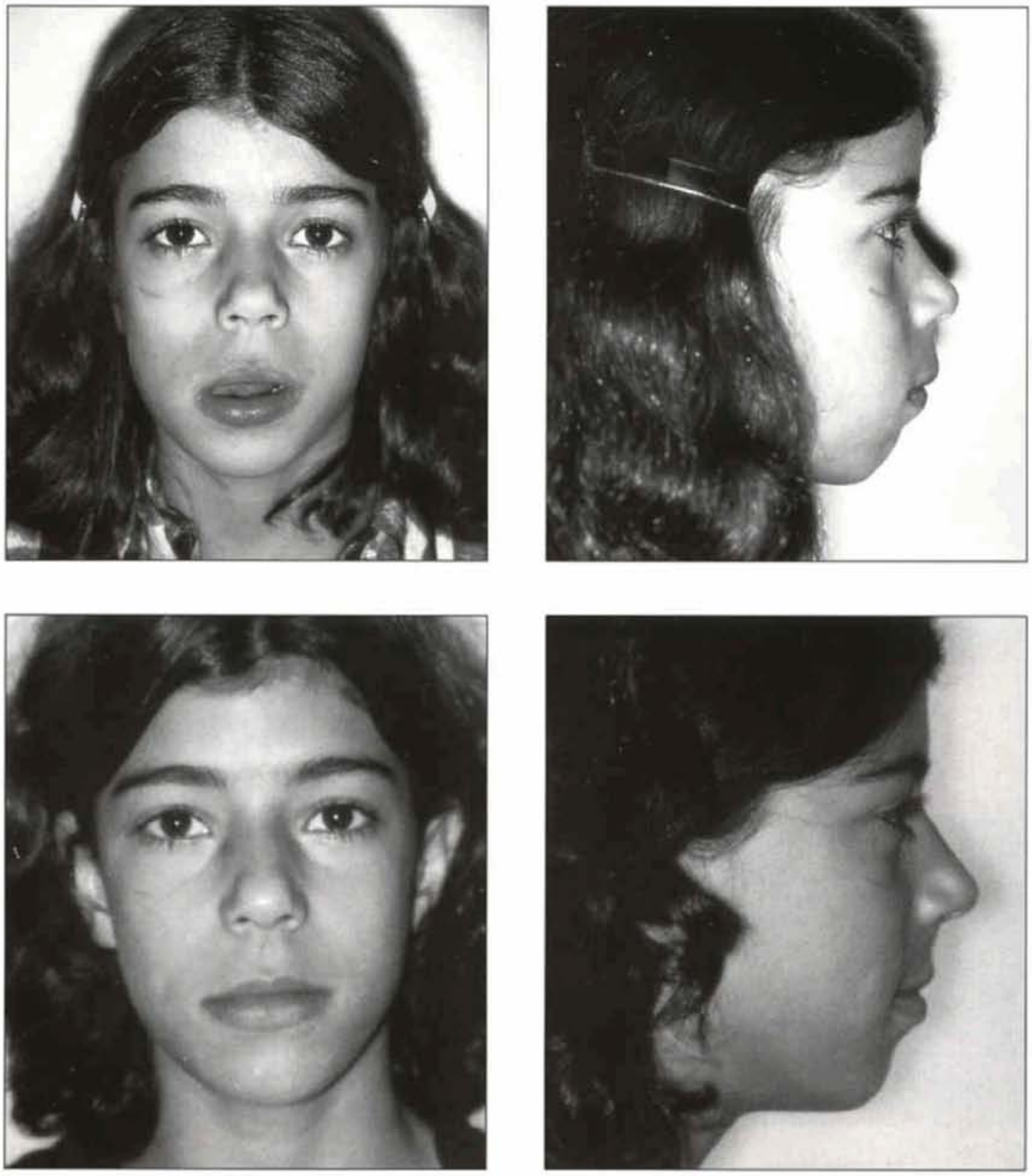

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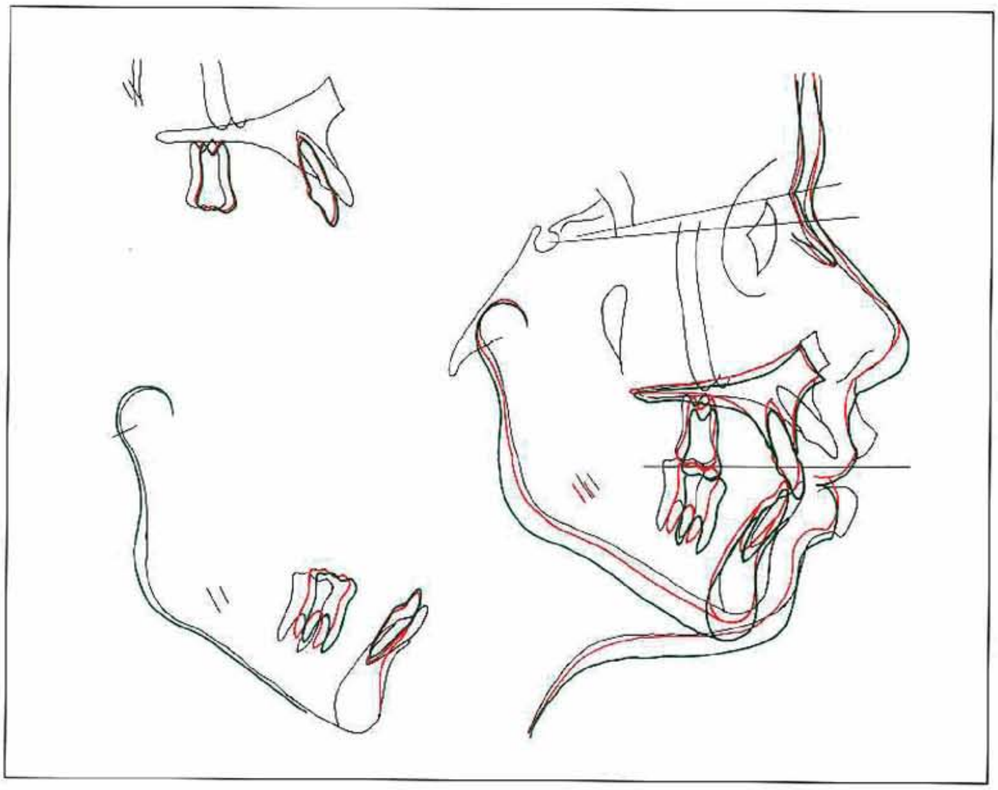

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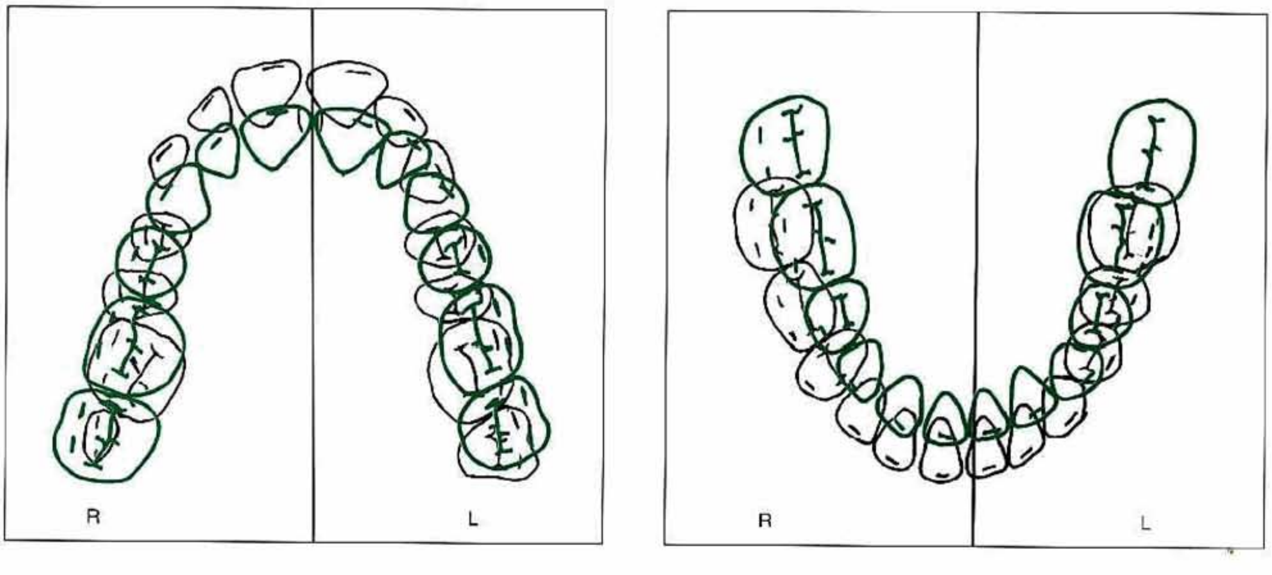
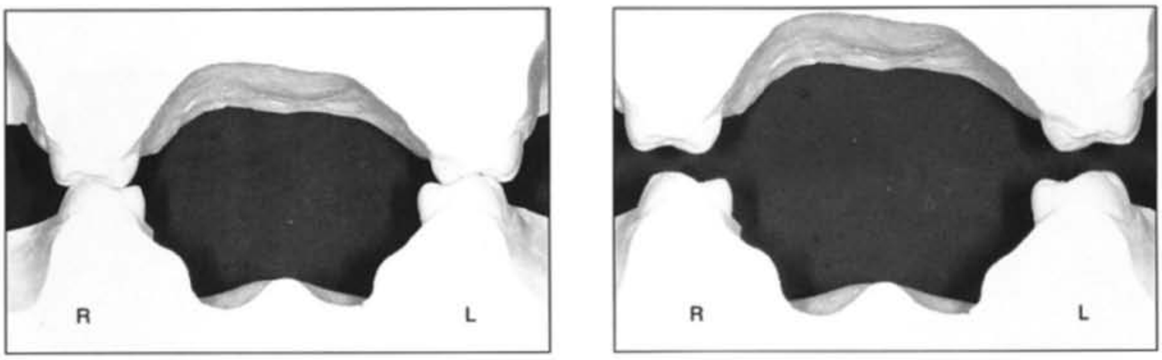


— original position — treatment outcome — 2 years postretention

Fig 4-16 A well-developed, untreated, wide arch. a, Casts showing little arch length inadequacy and broad arch widths. b, Sections cut through the mesial surfaces of the first molars. Axial inclinations are normal; that is, the wide arch is not caused by buccal tipping. c, The wide arch is associated with a broad face. d, The posteroanterior headfilm tracing shows wide apical bases and normal axial inclination of the molars.

a

b

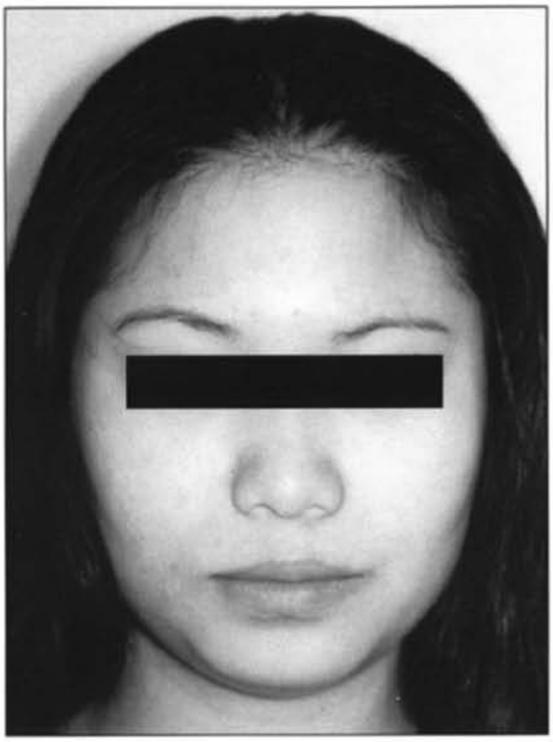


Using Expansion to Increase Arch Length

There are many reasons to expand an arch: (1) to correct a crossbite; (2) to harmonize arch widths in preparation for orthognathic surgery; and (3) to accommodate maxillomandibular growth differential. However, one of the most appealing uses of expansion is to solve an arch length inadequacy.

Crowding is associated with many factors, but the most common is narrow arches. An untreated patient with large arch widths and no crowding is shown in Fig 4-16. The large arch widths are not the result of buccally tipped teeth; buccolingual axial inclinations are normal (Fig 4-16b). Rather, the arch is wide because the face, maxilla, and mandible are wide (Figs 4-16c and 4-16d). In contrast, the patient in Fig 4-17 shows crowding in the mandible. Buccolingual axial inclination of the molars is normal with the exception of the lower molars, which are leaning lingually to compensate for the narrow maxilla. Note in particular the narrow width at the lower canines, which are leaning labially, masking an even narrower lower apical base. This patient has narrow arches because the facial bones are narrow (Figs 4-17c and 4-17d). Wide faces (brachycephaly) and narrow faces (dolichocephaly) represent different morphologies, and it is unrealistic to expect orthodontic tooth movement to transform a skeletally narrow arch into a skeletally wide arch. Even with rapid maxillary expansion (RME) and orthognathic surgery, the potential degree of stable change is limited.

c



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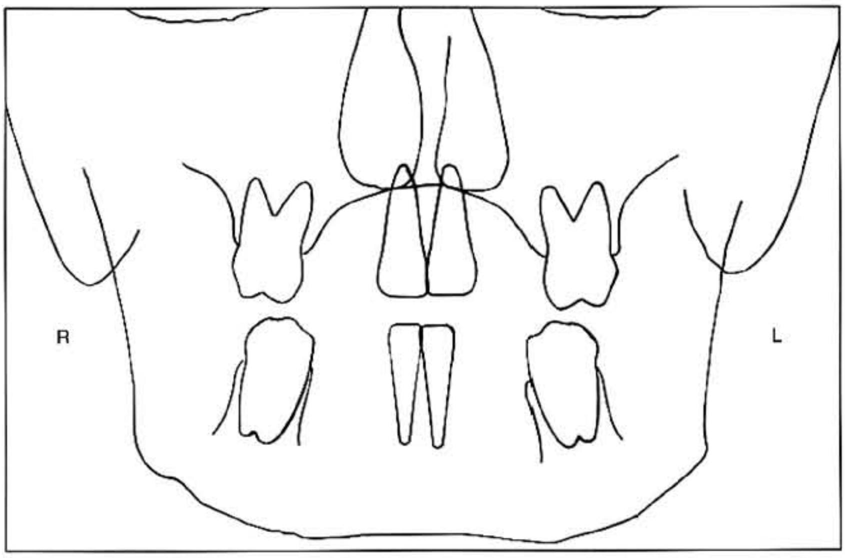
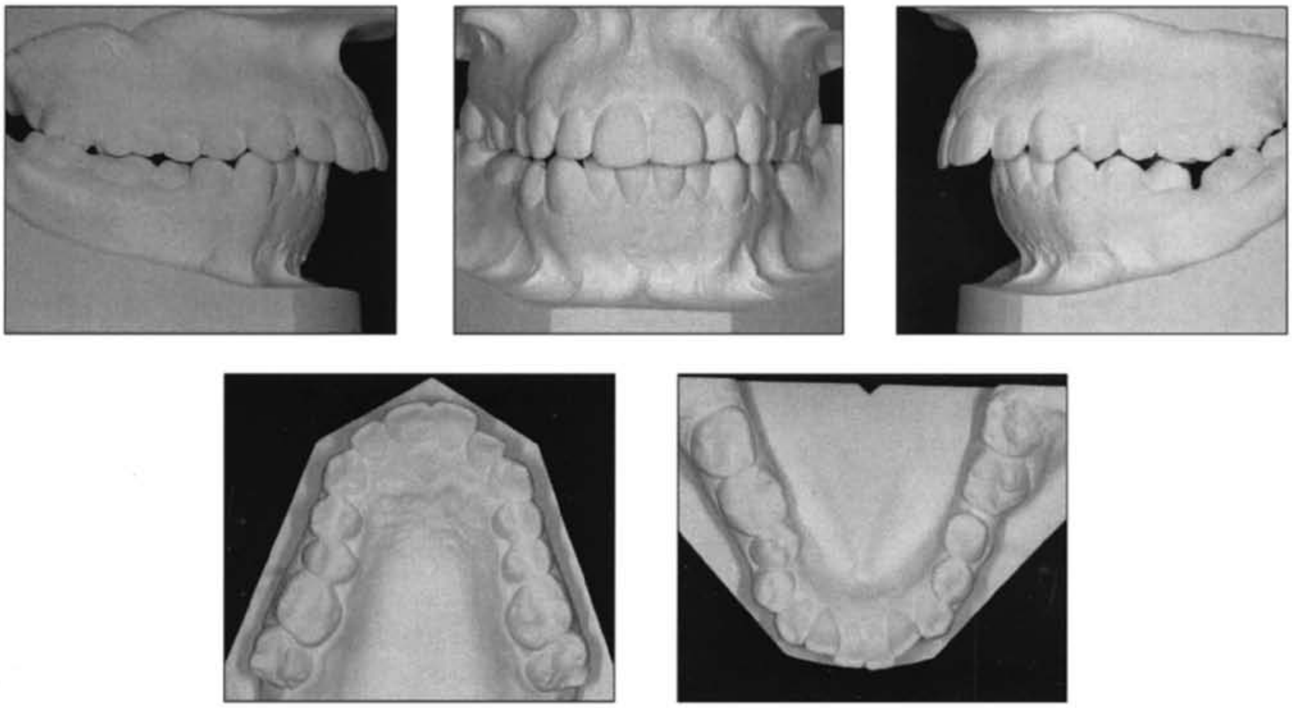


Fig 4-17 A narrow arch with crowding. a, Before-treatment study casts. Arch length inadequacies are seen in both upper and lower arches. b, Sections cut through the mesial surfaces of the canines and the first molars. Canines are flared, masking the narrow apical base widths. c, The narrow arch is associated with a narrow, tapering face. d, Maxillary basal bone is narrow; mandibular basal bone is proportionately wide with lingual compensations of the lower molars.

a



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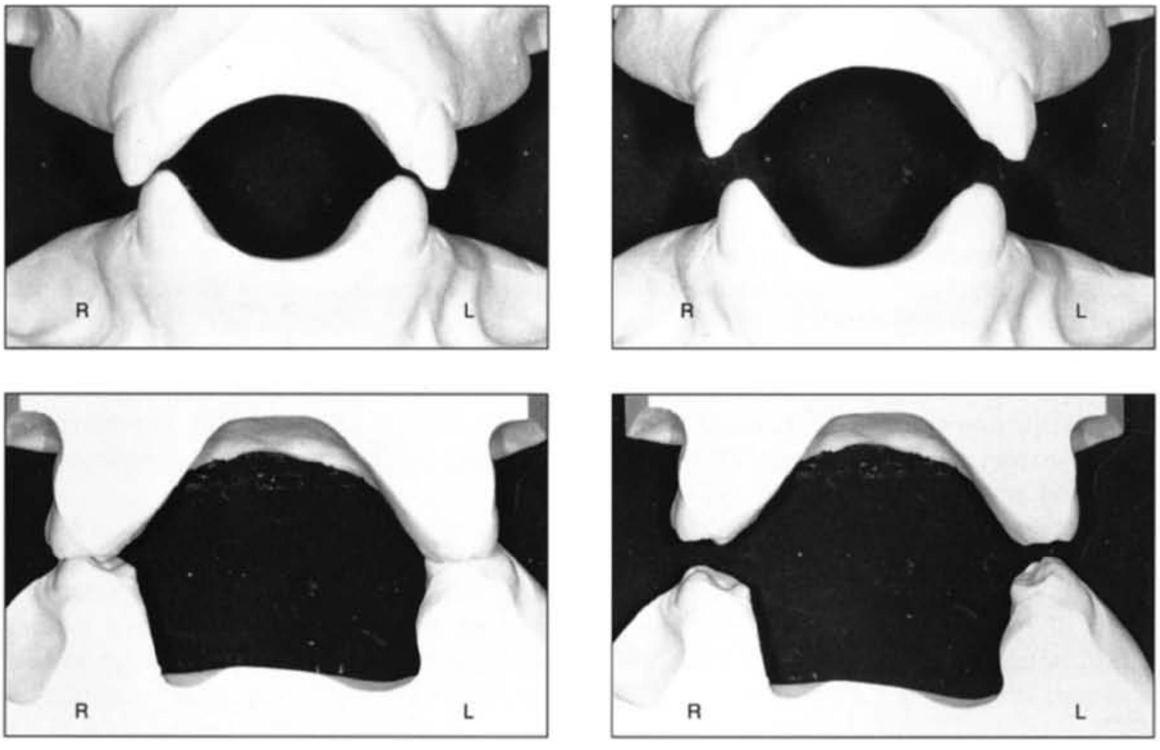

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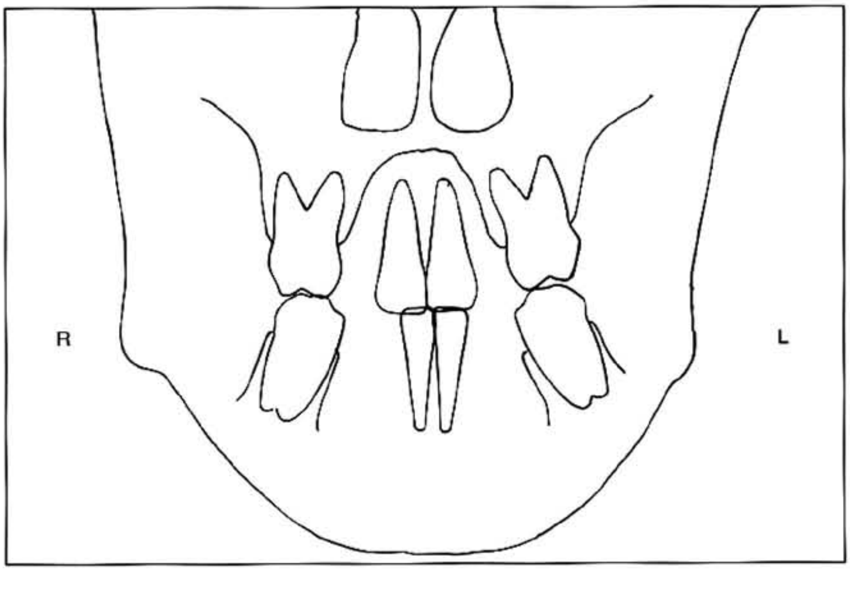
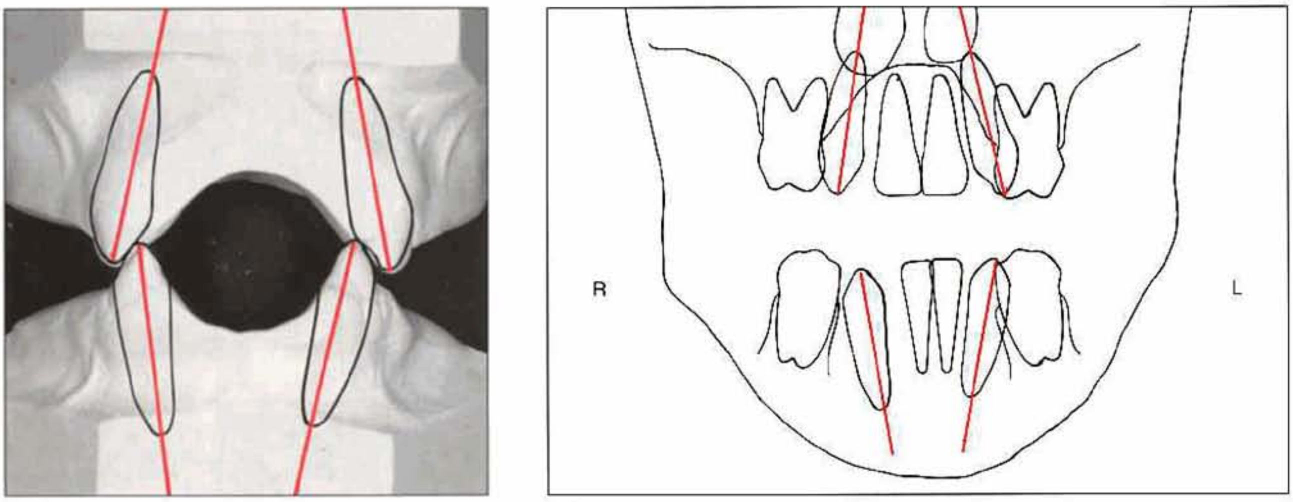


Fig 4-18 Narrow apical base in maxillary and mandibular canine region. a, Sections cut through the mesial surfaces of the canines. Canines are leaning labially. b, Posteroanterior headfilm tracing. Canines are leaning labially; it is rare to find canines leaning lingually in both arches when narrow arch widths are present.



a b

Is it possible to have narrow arches where teeth are in linguoversion? Rarely is this seen in both the upper and lower arches. When present, flaring the teeth buccally is not usually a stable treatment option since tight buccinator muscle activity is the etiologic factor responsible for this category of narrow arch. Most narrow arches have typical posterior axial inclinations, and frequently the canines lean to the labial and not to the lingual (Fig 4-18).

There is evidence that some flexibility exists in the amount of buccolingual expansion possible in the region of the molars; however, molar expansion does not lead to a significant increase in arch length. Considerably more interest is being shown in the region of the canine since increasing the canine width could solve some arch length inadequacies. A number of studies have shown that stable canine expansion is limited. In fact, there is a postretention tendency for canine widths to narrow somewhat from their pretreatment widths. We also know that merely maintaining canine widths does not ensure either stability or avoidance of posttreatment crowding of the lower anterior teeth, since other factors are involved in lower incisor crowding. While maintaining canine widths is considered a conservative procedure, this oversimplifies the establishment of arch widths and may lead to arch instability in certain patients or to a lack of awareness in patients in whom canine widths can be successfully expanded.

Some have claimed that it is possible to expand the apical base with the use of shields. The long-term stability of this type of expansion has not been documented. Rapid maxillary expansion has also been proposed for increasing canine widths, but long-term studies suggest that only minimal change, if any, can be obtained by this means. It has already been noted that stable increases in molar widths are possible. The use of various appliances, both old and new, is being proposed for widening arches, even though many studies have demonstrated the tendency of canines either to maintain their original widths or to narrow following treatment. The burden of proof rests with those who suggest using these appliances as valid and predictable procedures.

Fig 4-19 Canine overjet. If the cheek is not in contact with the lower canines, it is possible to expand them.

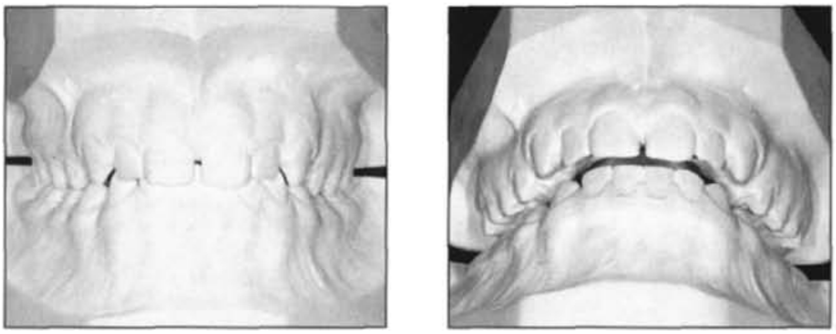
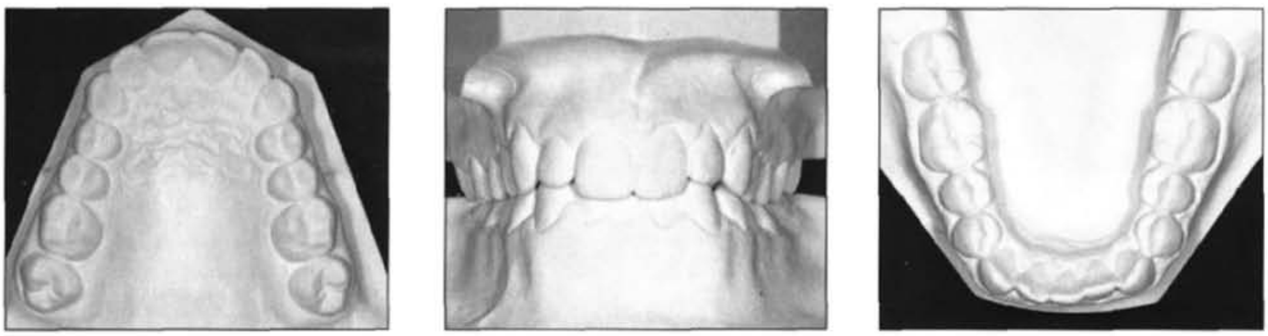


Fig 4-20 Patient in whom moderate lower canine expansion is indicated since the cheek is not in contact with the lower canine. a, Before-treatment study casts. b, Sections cut through the mesial surfaces of the canines and first molars. Canine overjet is present, allowing for lower canine expansion; molar axial inclinations are normal.

a



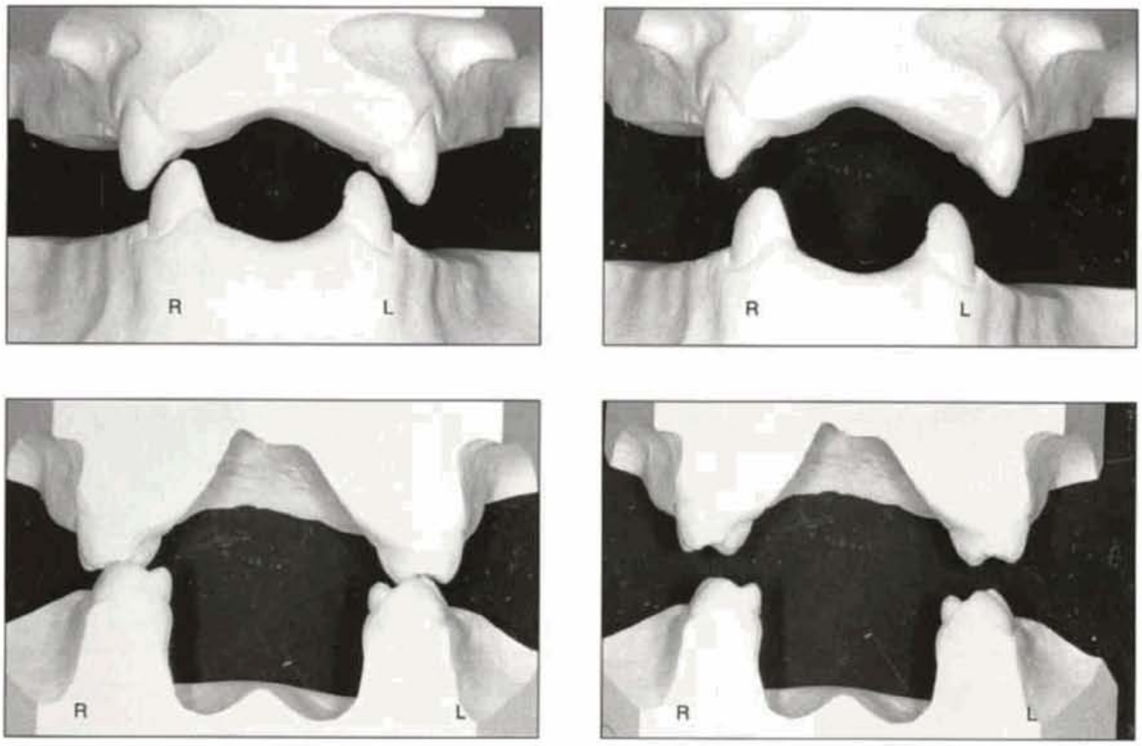
Canine Overjet: Expansion or Contraction?

A working hypothesis for establishing the labiolingual canine position is to observe the lip-cheek drape. Typically, when the mandible is in its rest position, the gingival one third of the lower canine crown is not in contact with the cheek. Flaring the canines further labially into the cheek invites potential relapse. Some patients exhibit a lack of arch harmony in the canine region, ie, canine overjet. Evaluating the lip-cheek contact with the canine facilitates the decision of whether to expand the lower canines or to contract the upper canines.

A malocclusion with deep overbite involving the canines is shown in Fig 4-19. During the clinical exam, the cheek was observed not to be in contact with the lower canines. This suggested that the overjet could be corrected by lower canine expansion. Lower canines that tend toward linguoversion are placed in that position by occlusal forces during their eruption.

Figure 4-20 shows a patient who exhibits similar deep overbite with canine overjet. The cast sections in Fig 4-20b show relatively normal axial inclinations of the molars and the canines. The cheek did not contact the lower canines, which allowed for lower canine expansion to correct the canine overjet. The upper left canine was tipped slightly labially.

b



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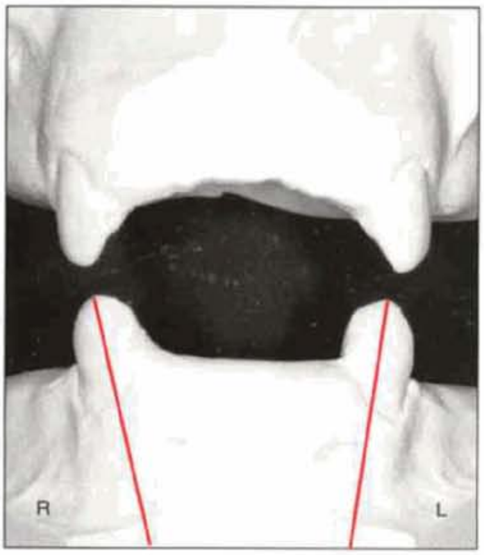

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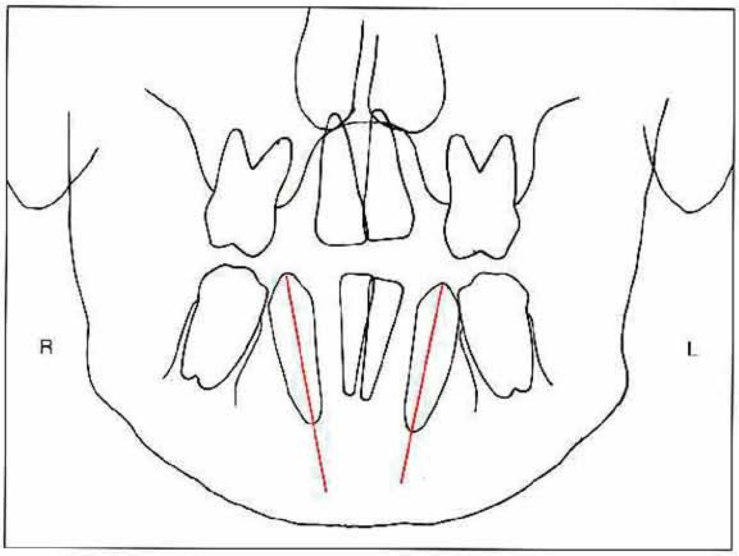
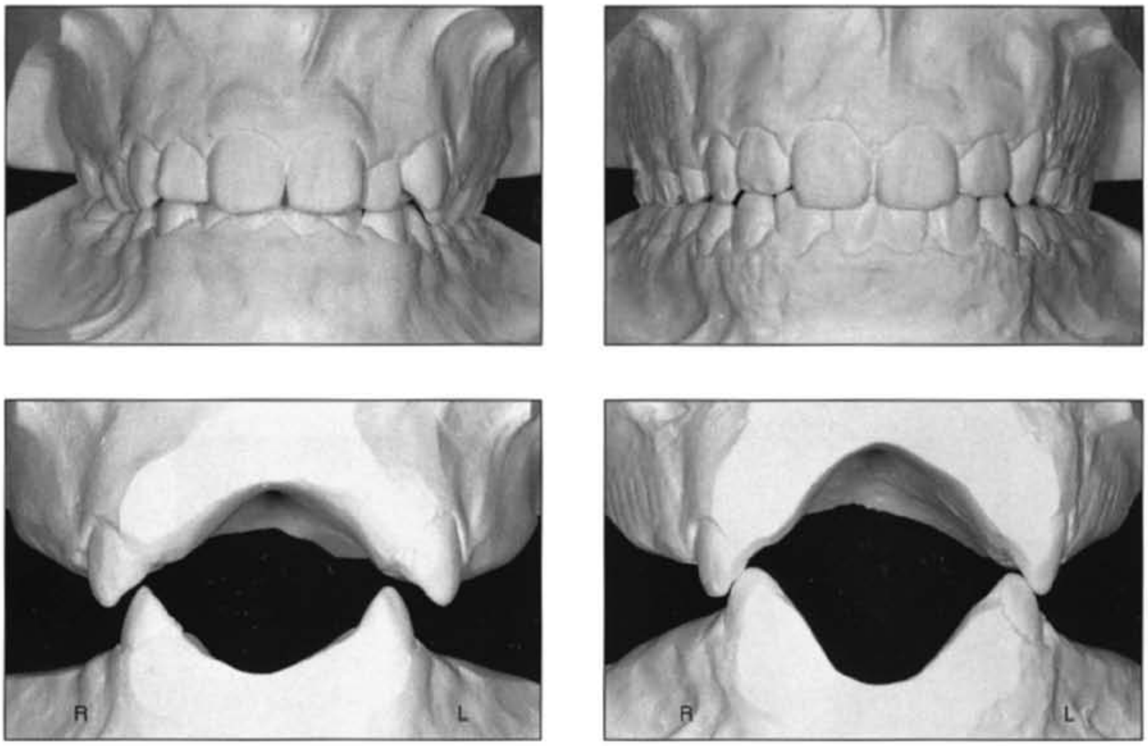


Fig 4-21 Canine expansion is not indicated: the lower canines are pressing into the cheek with no vestibular space and are labially inclined, compensating for a narrow apical base. a, Sections cut through the mesial surfaces of the canines. b, Posteroanterior headfilm tracing.

Fig 4-22 Canine overjet with tight lower cheek. The wide upper canines were narrowed to fit the stable lower canine position. a, Before- and after-treatment study casts. b, Before- and after-treatment sections cut through the mesial surfaces of the canines.

a b



The cast section through the canines in Fig 4-21 shows the lower canines to be flared labially; a deep overbite and overjet are also present. This patient had full contact of the cheek with the lower canines, so lower expansion was not considered a stable option. Note the flared lower canines on the posteroanterior headfilm (Fig 4-21b).

The canine overjet in Fig 4-22 was resolved by contracting the upper canines, since the cheek had tight contact with the lower canines. Contracting the upper canines also normalized their axial inclinations.

In a Class II malocclusion with an anteroposterior skeletal discrepancy, the retruded mandible occludes with the wider anterior part of the maxilla, leading to canine overjet. Figure 4-23 shows such a patient. The cheek is in contact with the lower canines; therefore, contracting the upper canines appears to be the only solution. Differential horizontal growth between the maxilla and the mandible can influence this decision. If desirable mandibular growth occurs during treatment, the advanced mandible places the lower canines in a narrower part of the upper arch, and little if any upper canine contraction is required. This growth is simulated in Fig 4-23b by advancing the lower study cast. Note that the canine overjet has been eliminated without altering tooth position.

In some patients, the canine overjet may be far worse than it appeared to be in the original malocclusion. The patient shown in Fig 4-24 has a lower canine displaced labially into the cheek, requiring considerable narrowing. This in turn increases the canine overjet, requiring the upper canines to be contracted even more.

a b

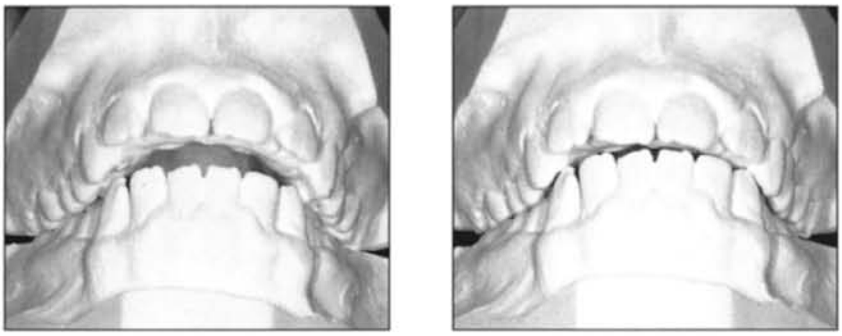


Fig 4-23 Upper-to-lower canine width discrepancy in a growing patient with a Class II malocclusion. With sufficient mandibular growth, narrowing of the upper canine width may not be necessary since the lower canines will be advanced to a narrower section of the upper arch. This differential mandibular growth can be simulated by sliding the mandibular cast forward relative to the maxillary study cast. a, Before-treatment study casts. b, The mandibular study cast has been advanced, eliminating the canine overjet.

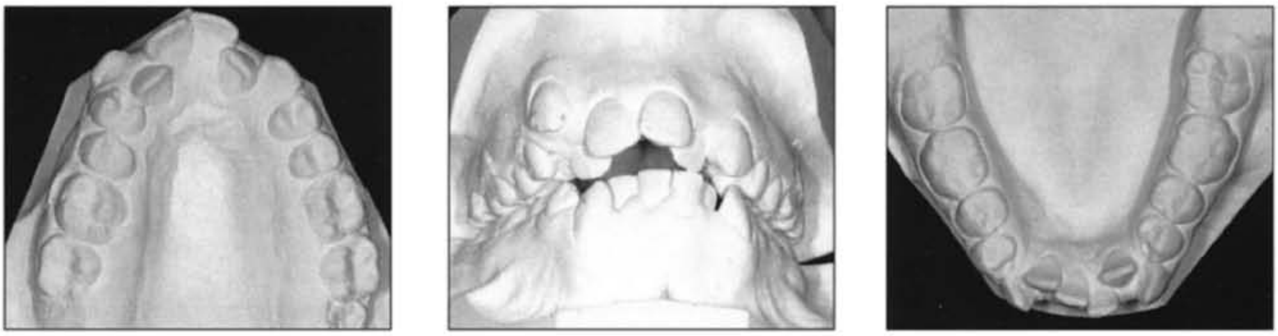
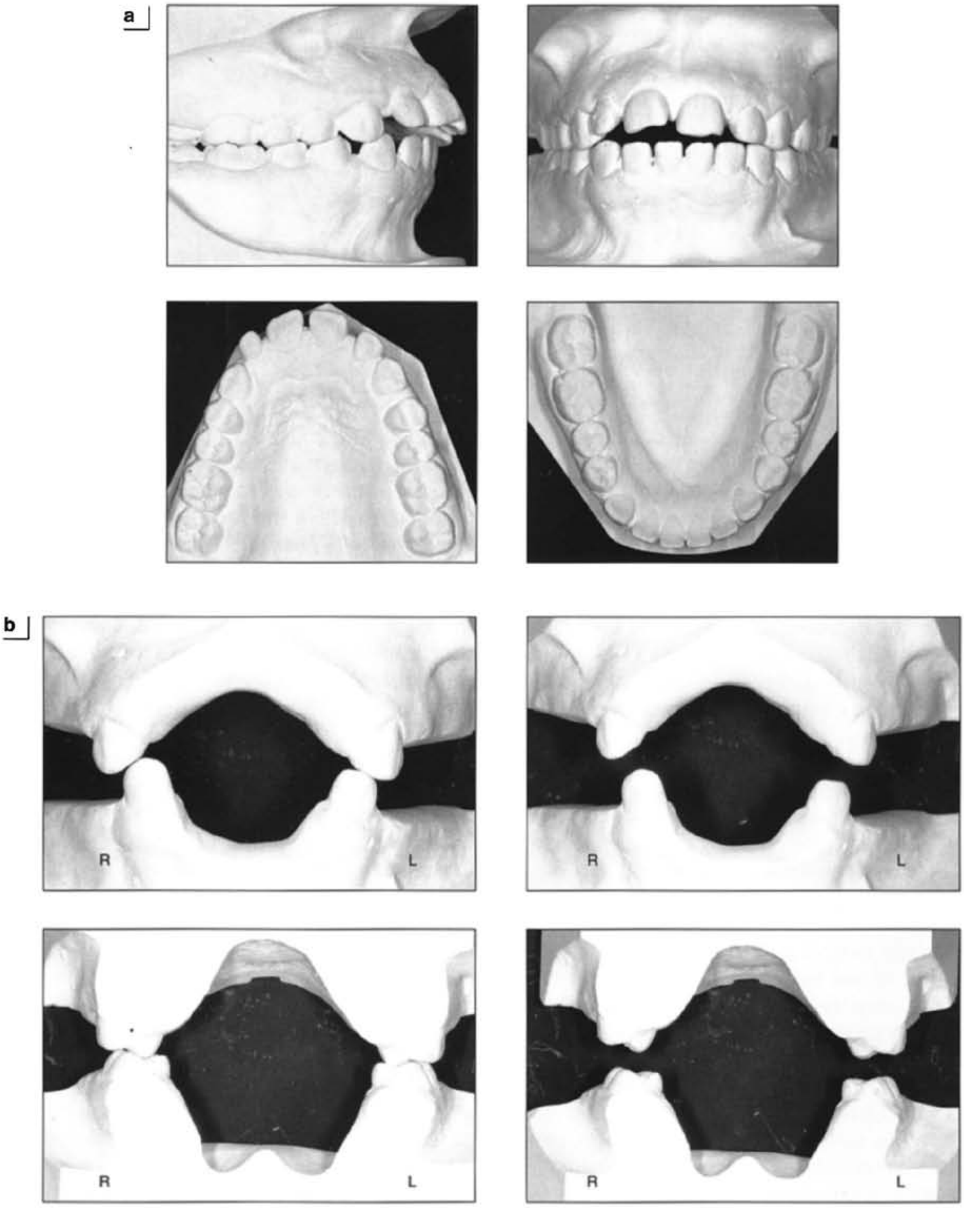


Fig 4-24 Lower arch length inadequacy is more severe than it appears. Both lower canines are positioned to the labial. Narrowing the lower left canine increases the canine overjet.

Generalized Arch Contraction

Patients who have malocclusions with generalized spacing frequently have large jaws and sometimes exert tongue pressures that flare the teeth. The patient shown in Fig 4-25 has generalized spacing and an open bite; during swallowing, the tongue presses anteriorly and projects through the incisors. Although the incisors and canines are flared, the molars have normal axial inclinations. One may be tempted to eliminate generalized spacing by contracting the arch widths and retracting the incisors. Relapse tendency, however, may be high following this rationale since the tongue most likely will reestablish the original arch form. Of course, the mechanics required to maintain incisor position while protracting the posterior teeth are demanding.

Fig 4-25 A wide arch with spacing. Space closure during treatment by anterior retraction and narrowing of the posterior widths may not be stable. Treatment may require posterior protraction to maintain the original arch form. a, Before-treatment study casts. b, Sections cut through the mesial surfaces of the canines and first molars. Canines are flared, but molars have normal axial inclinations.



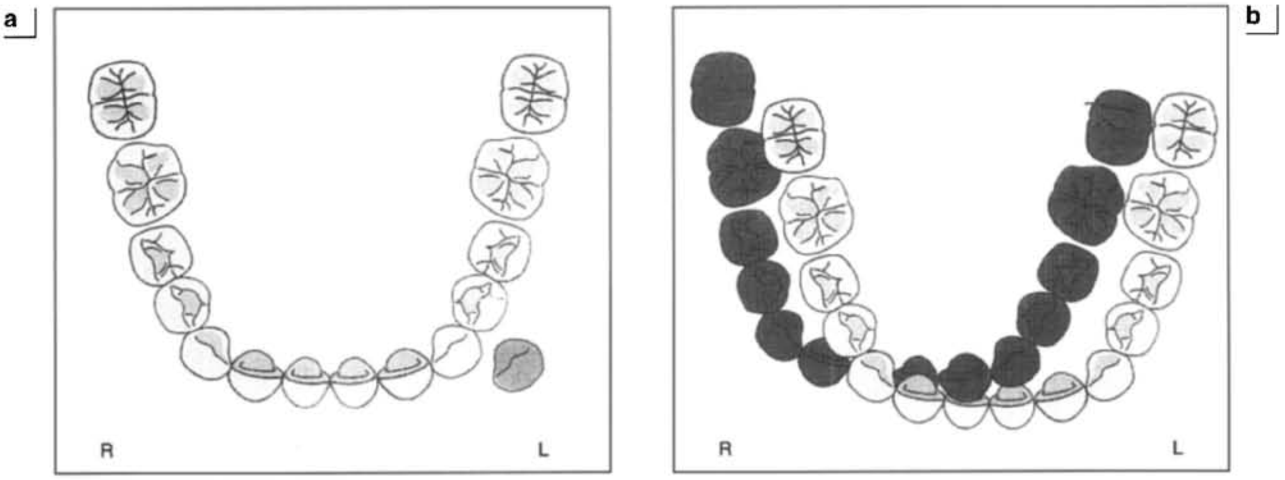


Fig 4-26 Fallacy of using canine width measurements alone. a, Lower left canine is wide. As the left canine is moved lingually, the canine width is narrowed. b, The correct narrowed canine width from 4-26a is shown; the arch, however, is skewed to the right, and the right canine is too wide. Canine width measurements are insufficient for evaluating stability with asymmetrical canine position.

Treating to the Original Canine Width

Since the pretreatment malocclusion is stable, it is often recommended that the original arch form and arch width, and particularly the canine width, be preserved. Generally, maintaining the canine width has some merit since expansion is not very stable in this region.

The idea of maintaining the original canine width as a treatment goal is based on a number of fallacies. Canines may be blocked out labially into the cheek, as is depicted in Fig 4-24; maintaining these widths is equivalent to expansion. Figure 4-26a schematically illustrates a canine position that is wide on the left side. The unshaded left canine is the correct width. After treatment, the canine widths are narrower; this may be an illusion, since only the left side has been narrowed. Figure 4-26b shows the correct canine width, but the final arch has been skewed to the right. If this were the treatment result, the original canine widths would have been maintained, but the right canine would now lie in the cheek. Canine labiolingual changes should therefore be evaluated separately in each quadrant.

In extraction cases, canines are moved distally to a wider part of the arch, so some increase in canine width is possible. This should not be considered an expansion but rather a maintenance of the arch width by allowing the canine to follow the original arch form. One must be assured that the canines have been successfully retracted without losing anchorage before assuming that the canines are in a wider part of the arch. A headfilm before debanding can be useful in making the final determination of arch form since, along with the occlusogram, it allows for the determination of how far lingually the incisors have been retracted and where the canines and molars are positioned after the space closure (Fig 4-27).

As noted above, merely maintaining the original canine widths ignores the roles played by the soft tissues and other functional factors in determining stable canine width changes. A more dynamic approach considers muscular forces, growth, and the changing functional matrix of the face.

In the next chapter, discussion of arch form determination continues with consideration of the anteroposterior position of the incisors.

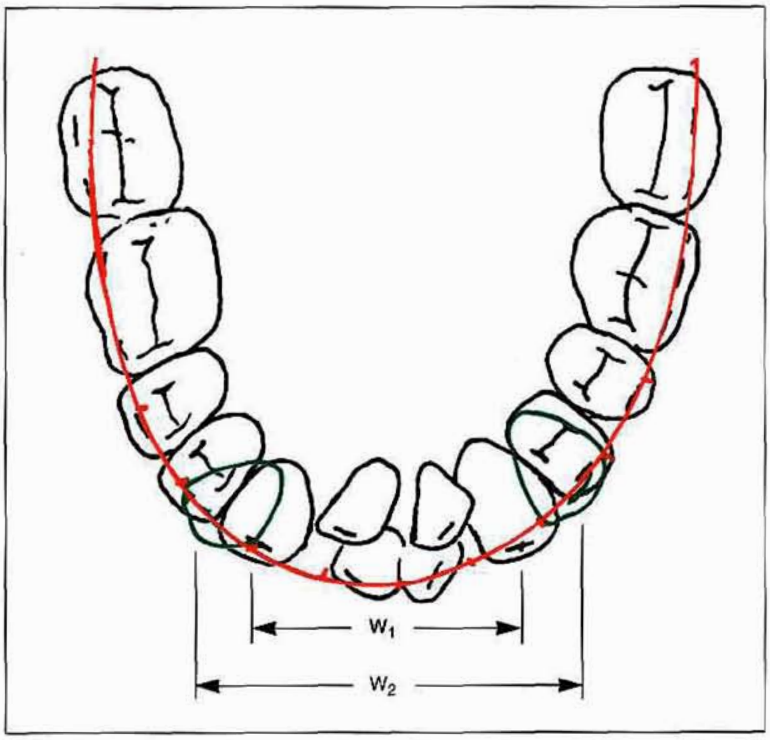


Fig 4-27 As the canines are retracted to a wider part of the arch, their widths increase; however, the basic arch form remains. Progress headfilms along with occlusograms allow a determination of the amount of canine retraction so that canine widths can be accurately determined.

5

Chapter

Arch Form and Dimension: Anteroposterior Positioning of the Incisors

Much has been written about positioning of the incisors, particularly the lower incisors, in orthodontic treatment planning. Edward Angle believed that if the incisors were aligned, bone would grow, producing a stable, esthetic result. Other early orthodontists such as Calvin Case believed that the anteroposterior position of the incisors was the most important factor in achieving good facial esthetics. In Germany, P. Simon developed the guideline known as the "law of the canine," a perpendicular line from orbitale to Frankfort horizontal that passes through the canine crown.

In the United States, cephalometrics was being developed as a guide to determining the ideal position of the incisors, leading many to accept the notion that the mean position or the axial inclination of an incisor would be a desirable treatment goal. However, the use of cephalometric treatment norms to determine incisor position can be both deceptive and misleading. For example, in some samples of good untreated occlusions, the inclination of the lower incisor to Frankfort horizontal is, on average, approximately 65 degrees, and the standard deviation can be as large as 4 degrees. This means that at three standard deviations (99% of the population) there can be a variation of 12 degrees on either side of the mean—and yet all of these occlusions are considered "good." Since all of these occlusions are stable, the mean or median incisor position is no better than those at the extremes. W. B. Downs's sample included only "ideal" occlusions that, like the others, showed a large variation around the mean values. Unfortunately, many clinicians emphasized only the mean values in Downs's analysis, ignoring the variation in these stable untreated occlusions. In the Burstone-Herron sample, which is based on good faces rather than good occlusions, a standard deviation of +5.2 degrees was observed in incisor inclination (Fig 5-1), suggesting that even among individuals with stable occlusions and attractive faces a broad variation is found in incisor inclination. Going back to Downs's analysis, the upper incisor to the point A–pogonion line has a mean value of 2.0 mm and a standard deviation of 2.0 mm; thus, at three standard deviations, upper incisors can be as far as 6 mm on either side of the mean, and yet the occlusion can be excellent.

Another confounding factor is that many malocclusions involve skeletal discrepancies, which represent a different population from that just described. With anteroposterior skeletal variations, some compensations occur in the position of the dentition. In a Class III skeletal malocclusion, for example, when the mandible is

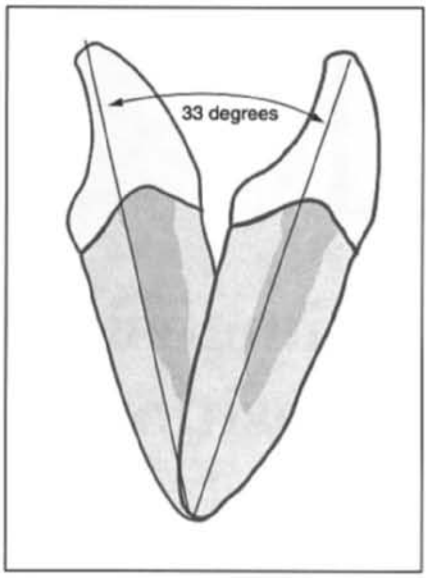


Fig 5-1 Variations of three standard deviations in the position of the lower incisors in subjects with stable occlusions and attractive faces.

Fig 5-2 Class III malocclusion with a large point A–point B discrepancy. The underjet is less than the skeletal discrepancy as a result of the compensation of the upper and lower incisors.

forward of the maxilla, the lower incisors often compensate for the prognathism by leaning lingually, while the upper incisors often lean labially more than average. In the lateral headfilm shown in Fig 5-2, point B is anterior to point A. The flaring of the upper incisors and the lingual inclination of the lower incisors to the mandibular plane have partially compensated for this prognathic denture base relationship. Uprighting the incisors to their normal values would produce an underjet similar in degree to the point A–point B discrepancy.

Patient GC, who has a Class III malocclusion, shows normal upper incisor position and axial inclination, but the lower incisors have compensated by leaning lingually (Fig 5-3). A tight lower lip has retruded the lower incisors in a lingual direction, and so their most stable position would be lingual to their present position. Stable, nonsurgical treatment of this patient thus requires that the lower incisors either be maintained in their current position or moved somewhat lingually, rather than labially toward their "mean" position.

Despite a large prognathic point A–point B discrepancy, the untreated occlusion in patient KB (Fig 5-4) is normal and stable, and the soft tissue facial profile is also fairly normal. In most people, upper and lower lip thicknesses are identical, but in patient KB, the thicker upper lip appears to compensate for the skeletal discrepancy.

In many Class III skeletal patterns, the lower incisors incline lingually because of a tight lower lip. If these patients are treated nonsurgically, it may be desirable to maintain these compensations since the position of the lower incisors is stable. Hence, the most desirable and stable position can be far from the mean. Conversely, when these patients are treated surgically a common presurgical orthodontic treatment goal is to eliminate—or at least to minimize—these compensations in axial inclinations in order to achieve a good facial result.

Compensations away from the mean are also seen in Class II skeletal malocclusions. In patient MF, who has an untreated Class II malocclusion (Fig 5-5), the lower incisors are flared and the upper incisors are retruded. In the Class II skeletal pattern, these dental compensations have produced normal incisor overjet. Uprighting the lower incisors and retracting the upper incisors would not improve incisor stability or lip esthetics. Patient DP shows a Class II skeletal pattern with a relatively normal occlusion as well as normal overjet (Fig 5-6). The flared lower incisors compensate for the skeletal retrognathism.

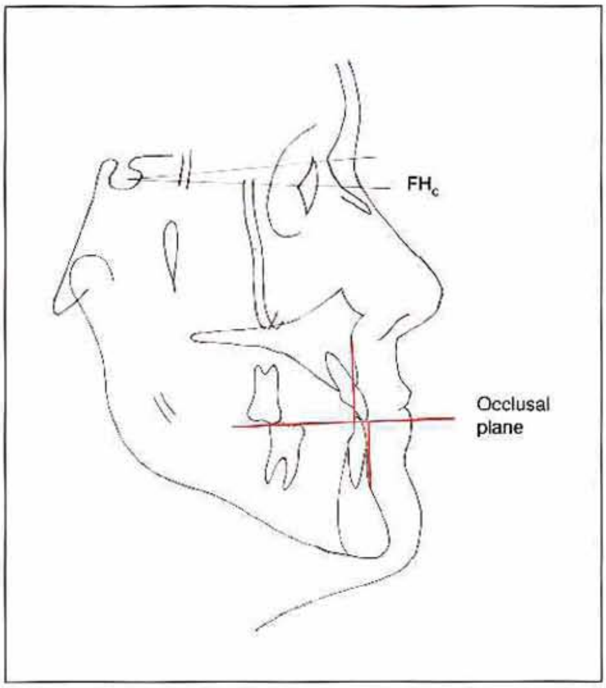


Fig 5-3 Patient GC. Nearly normal overjet is a result of the compensatory lingual axial inclination of the lower incisors. The stable position of the lower incisor lies lingual to the cephalometric mean.

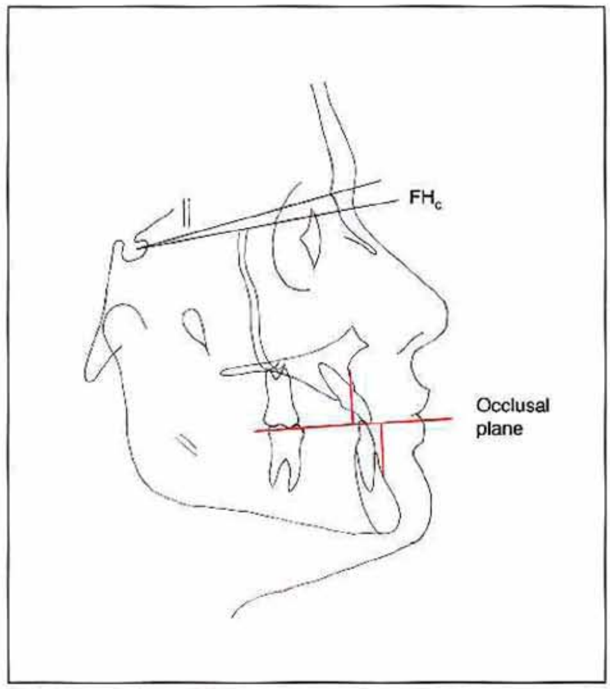


Fig 5-4 Patient KB. Compensations in the upper and lower incisors result in normal overjet. Note how the variation in soft tissue lip thickness masks the Class III skeletal pattern.

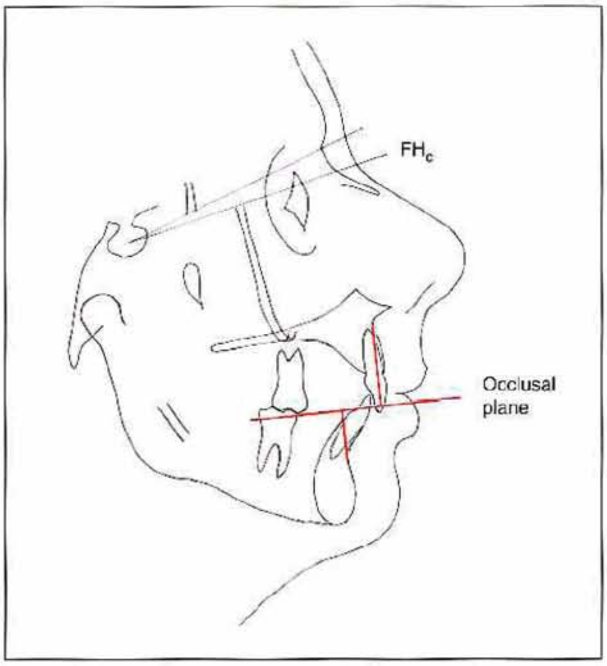


Fig 5-5 Patient MF. Flared lower and retruded upper incisors compensate for the Class II skeletal discrepancy.

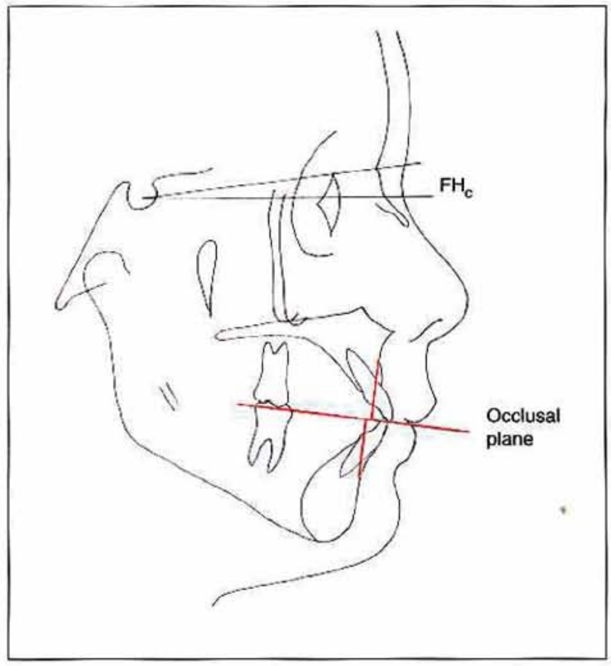


Fig 5-6 Patient DP. Normal occlusion with a small point A-point B discrepancy. The flared lower incisors have compensated for the skeletal discrepancy.

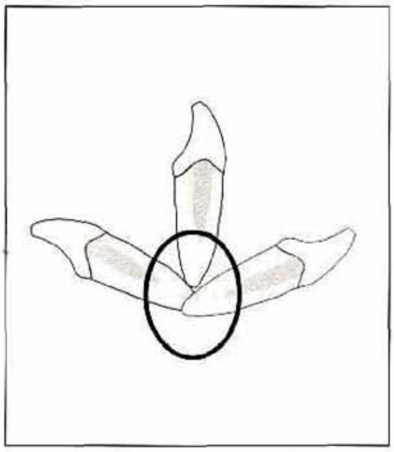


Fig 5-7 The concept of placing teeth over basal bone is minimally helpful since many incisor positions that meet these criteria are undesirable. All roots shown are within the basal bone (oval).

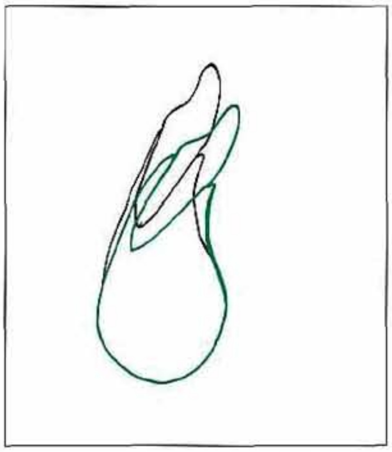


Fig 5-8a The lower incisor was flared during treatment. The alveolar process with point B was remodeled; point B is an alveolar landmark that can be modified by tooth movement.

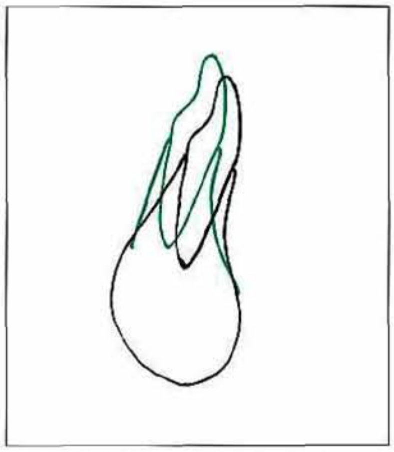


Fig 5-8b The lower incisor was translated lingually during treatment. Both the labial and lingual plates of bone show remodeling changes. A cephalometric angular measurement of the axial inclination of the lower incisor is insufficient to plan or describe this type of tooth movement.

Cephalometrics allows one to examine the components of a malocclusion and to estimate growth of the face. It may be used to plan a course of treatment and to document the before and after effects of treatment as a means of evaluating its success. While useful as a diagnostic tool, cephalometrics is misapplied when means or averages are used as treatment goals. The goals of treatment should be stability, pleasing facial esthetics, and normal oral and dental function rather than the achievement of simple arithmetic means.

The notion of positioning the lower incisors over basal bone was developed by C. H. Tweed. This is a nebulous concept, however, since teeth can assume many different positions and axial inclinations and still be over basal bone provided that their roots are maintained in supporting bone (Fig 5-7). The limitations of incisor positioning probably relate more to concerns about stability and pleasing facial esthetics than to anatomy.

The lower incisors have been repositioned in the two patients shown in Figs 5-8a and 5-8b. In Fig 5-8a, the incisor has been flared, resulting in remodeling in the labial plate of the alveolar process and the anterior repositioning of point B. The limits of labial tipping are not anatomic provided that the roots are not positioned labially through the basal portion of the mandible. Excessive labial tipping could result in periodontal problems and loss of bone, although documentation of this undesirable sequelae is presently lacking. Other contraindications to incisor flaring include questionable treatment stability and undesirable facial esthetics, but these limitations are not anatomic.

In Fig 5-8b, the lower incisor has been translated lingually, causing alveolar remodeling on the labial and lingual plates. Point B has been repositioned lingually within the confines of the support bone of the apical base. The use of a cephalometric angular measurement, such as the lower incisor long axis to a reference plane, can lead to error in describing and determining lower incisor position. As shown in Fig 5-8b, an angle alone will not describe translatory movement of the tooth and will also be affected by any variation in the reference plane.

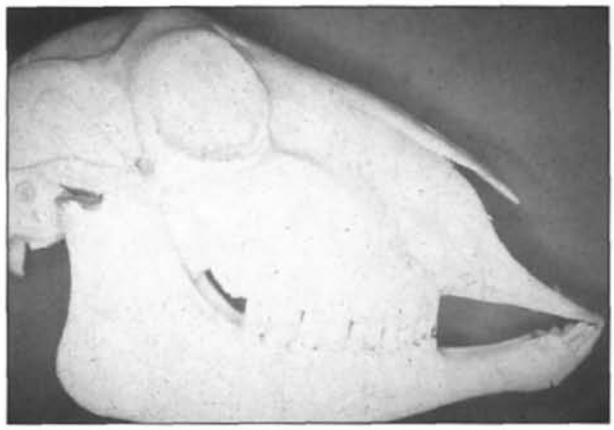


Fig 5-9 Herbivore skull. Protrusive lower incisors demonstrate the biologic principle of stable variation in lower incisor axial inclination.

In comparative anatomy, broad variation is found in tooth position. In the dentition of a herbivore, for example, lower incisors usually are very protrusive, and yet they are stable, functional, and positioned within basal bone (Fig 5-9). A rational approach to determining the position of the anterior teeth must begin by defining benefits for the patient—facial esthetics, function, and stability of the treatment result—and should not be based on a set of arithmetic means.

Incisor Position and Facial Esthetics

Philosophers and artists have tried for centuries to define beauty, and yet orthodontists claim special knowledge of what constitutes a beautiful face. The problem is more practical than philosophical. In most societies faces that deviate considerably from the average are not considered attractive. In the Burstone-Herron sample of faces chosen by nonorthodontists as being attractive, the average face was similar to those used in commercial advertising. However, what was considered to be average varied considerably, which suggests that not all people, and not all our patients, should look alike.

In this chapter we restrict our analysis to the facial profile, but the reader should remember that facial esthetics is three-dimensional and the frontal or nonoriented view is very important to the patient.

The facial profile comprises all structures from the hairline to the neck. Whereas tooth movement primarily affects the protrusion-retrusion of the lips, growth, surgery, and facial orthopedics have broader influence over the nose and chin. A patient's lip protrusion should never be based exclusively on a dentoskeletal measurement, since the degree of soft tissue thickness covering the teeth and bones varies considerably from one person to the next. Note, for example, the differences in lip thickness in the patients shown in Fig 5-10. Moreover, upper and lower lip thicknesses may not be proportional (Figs 5-10a and 5-10d). The soft tissue in the chin area does not always reflect the morphology of the hard tissue in the chin area (Fig 5-10d). It is possible that two patients with similar dentoskeletal morphologies will have entirely different lip protrusions (Figs 5-11a and 5-11b).

Figure 5-12 shows the lateral headfilm tracings of three patients who were all treated according to the same dentoskeletal standard; that is, the lower incisors were positioned on the point A–pogonion line. Patient a, who has thick upper and lower lips, exhibits extreme lip protrusion. The thin soft tissue covering in the chin area accentuates this patient's lip protrusion and the overall convexity of the facial profile (Fig 5-12a). Patient b has aver-

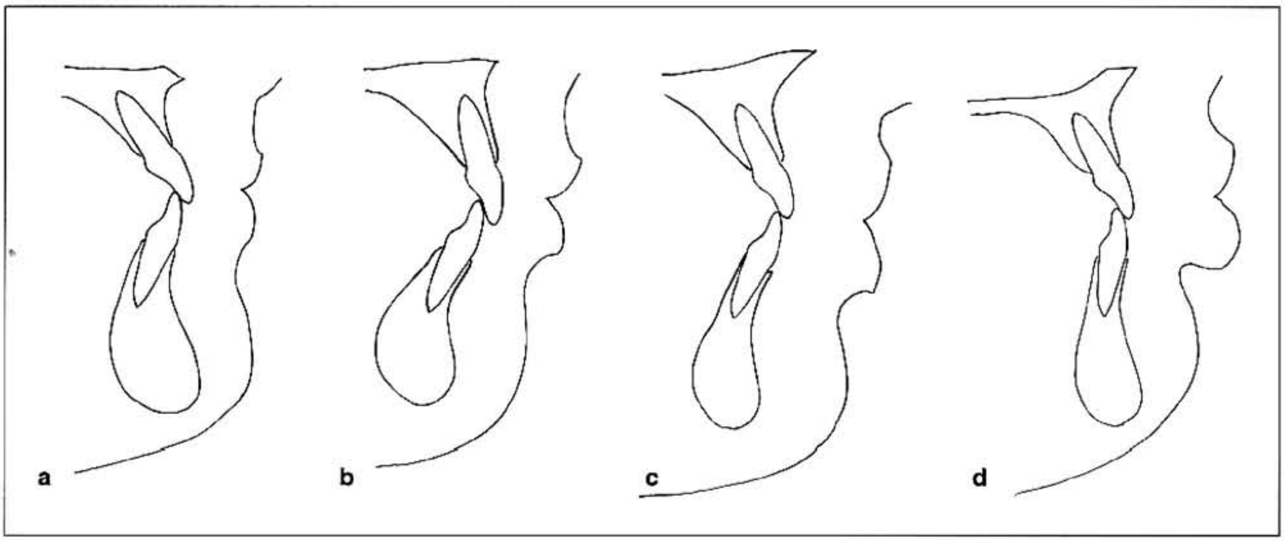


Fig 5-10 A large variation is found among patients in lip and soft tissue chin thickness. To achieve good facial esthetics, soft tissue thicknesses must be taken into consideration.

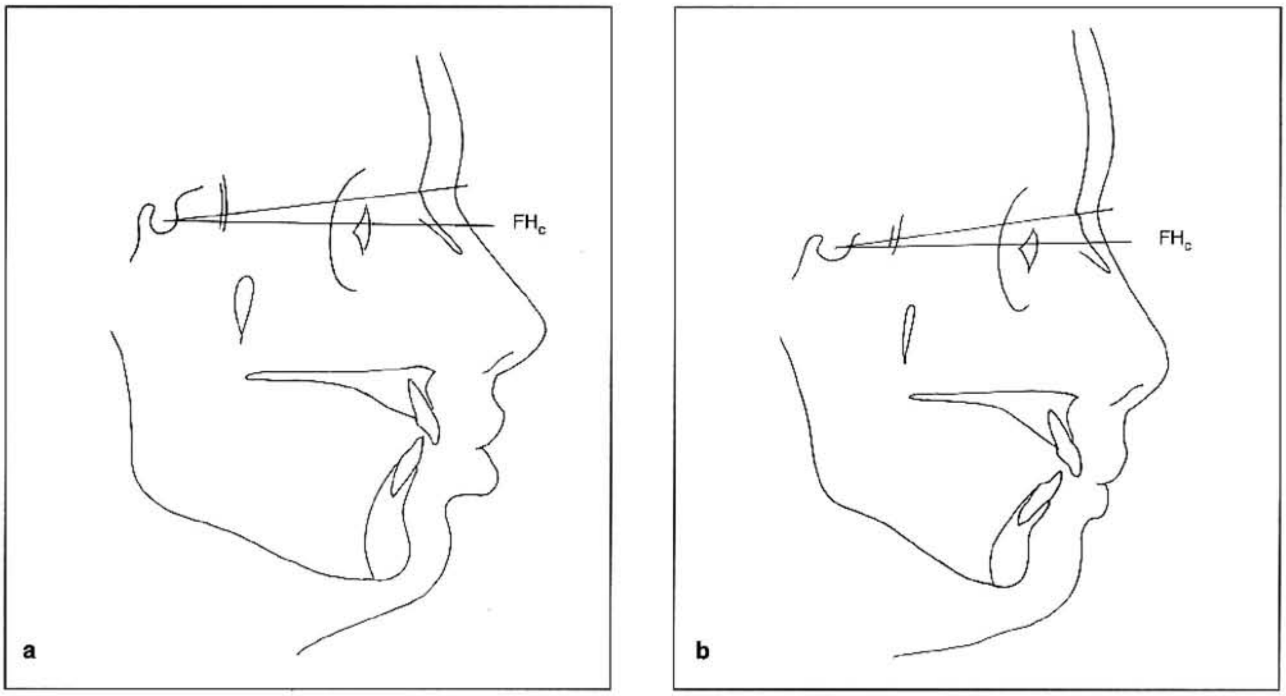


Fig 5-11 Two patients with similar dentoskeletal patterns. Note the difference in soft tissue profile caused by the variations in lip-chin thickness.

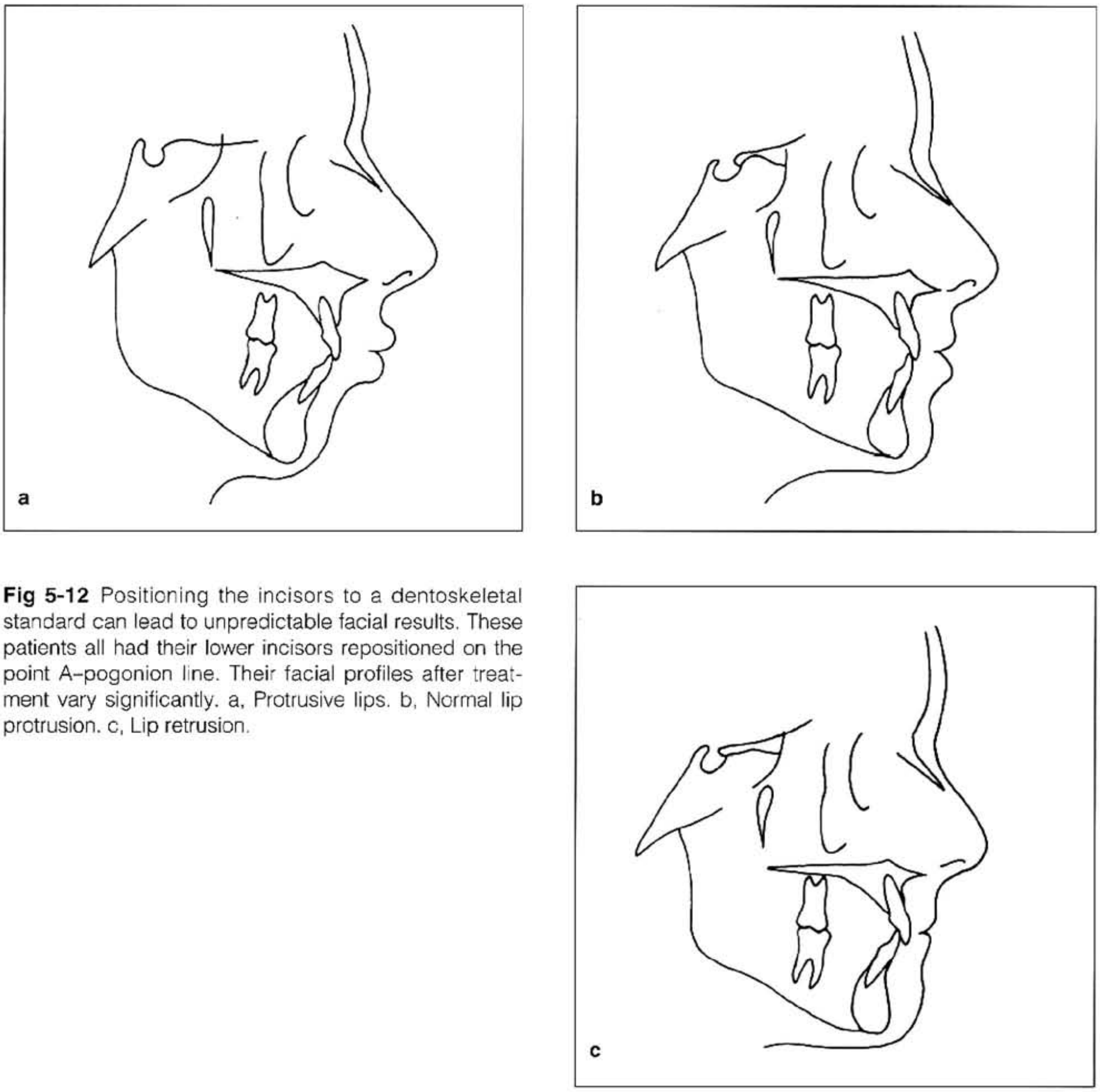


Fig 5-12 Positioning the incisors to a dentoskeletal standard can lead to unpredictable facial results. These patients all had their lower incisors repositioned on the point A–pogonion line. Their facial profiles after treatment vary significantly. a, Protrusive lips. b, Normal lip protrusion. c, Lip retrusion.

age lip protrusion and average soft tissue facial convexity (Fig 5-12b). Patient c has retrusive lips that are also thin in relation to the thickness of the soft tissue in the chin area and the thickness of the area from point A to subnasale (Fig 5-12c). As this comparison illustrates, no arbitrary cephalometric standard can be used as a predictable guide to facial appearance—every patient requires a soft tissue and facial evaluation.

A typical Caucasian American profile is shown in Fig 5-13. The total facial convexity, from soft tissue glabella to subnasale to soft tissue pogonion, is 13.0 degrees (angle a in Fig 5-13). Upper and lower lip protrusion is measured in relation to the subnasale–pogonion line, which offers the advantage of not being directly associated with the nose. Typically, the upper lip protrudes 3.5 mm and the lower lip protrudes 3.0 mm from the

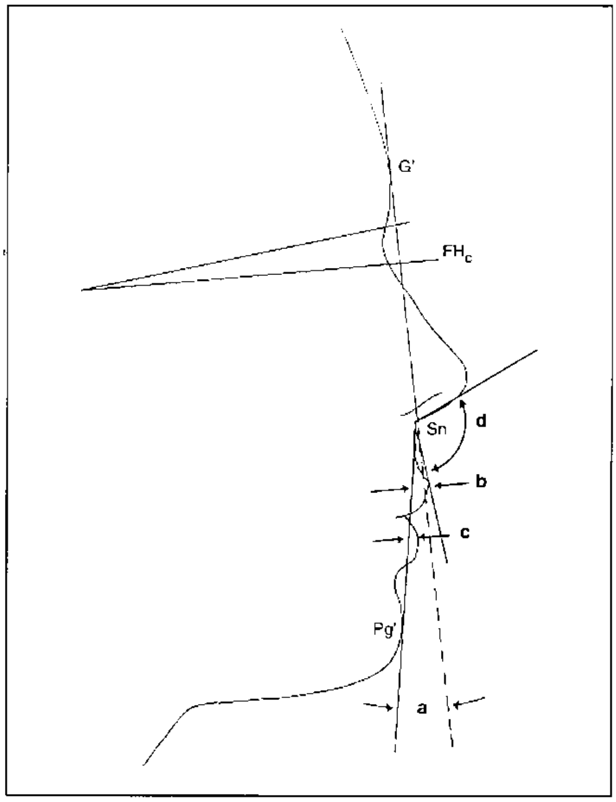


Fig 5-13 Soft tissue profile measurements. a, Angle of facial convexity. b and c, Lip protrusion measured in relation to the Sn–Pg' line. d, Nasolabial angle.

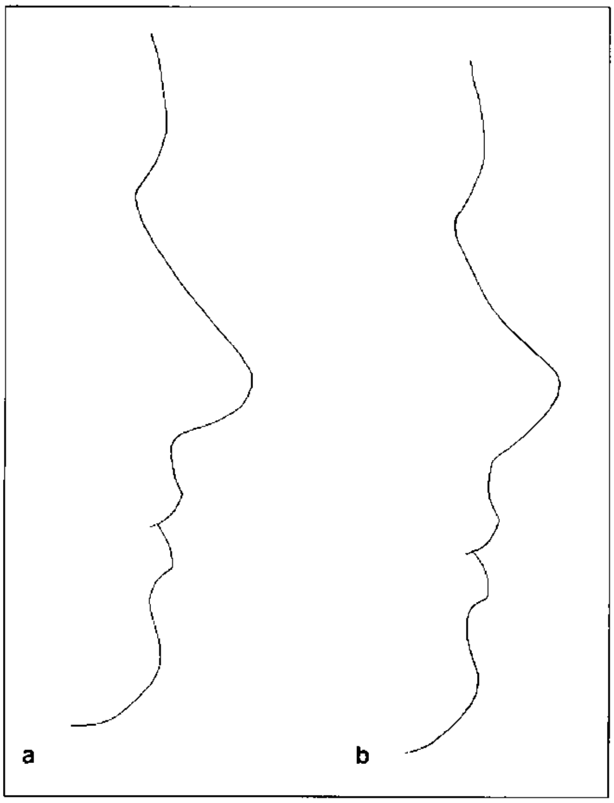


Fig 5-14 Tracings of two identical profiles (a and b) with the exception of the nose and the columella cant. Although the nasolabial angle is more obtuse than average in b, the facial profile is pleasing. Variation in the nose and the columellar angle is more acceptable than variation in the upper lip inclination.

subnasale–soft tissue pogonion line (b and c, respectively, in Fig 5-13). This measurement of lip protrusion remains relatively stable, reducing only slightly with age. The lip-chin angle (pogonion–lower lip–upper lip) approximates 0 degrees and also remains relatively stable over time.

The relationship of the nose to the upper lip is very important. The nasolabial angle (d in Fig 5-13) averages 110 degrees and has two components: (1) the inclination of the upper lip, which is approximately 100 degrees to Frankfort horizontal, and (2) the inclination of the columella nasi. In patients with a greater than average nasolabial angle, it is important to distinguish between the two inclinations that produce it: a posteriorly inclined upper lip and a superiorly inclined columella nasi.

A posteriorly inclined upper lip that results in an excessively obtuse nasolabial angle can greatly compromise the facial esthetics in the treatment of a Class II, division 1 malocclusion. This familiar "orthodontic look" is produced when a naturally obtuse nasolabial angle is aggravated by additional backward inclination of the upper lip during incisor retraction. Less compromising is treatment of a Class ff, division 1 malocclusion in a patient with an excessively obtuse nasolabial angle caused by an upturned nose—that is, an upwardly inclined columellar line (or cant). The two profiles shown in Fig 5-14 are identical with the exception of the columellar cant and nose shape. In Fig 5-14b, it would be unreasonable to normalize the nasolabial angle by protruding the upper lip since variation in nose

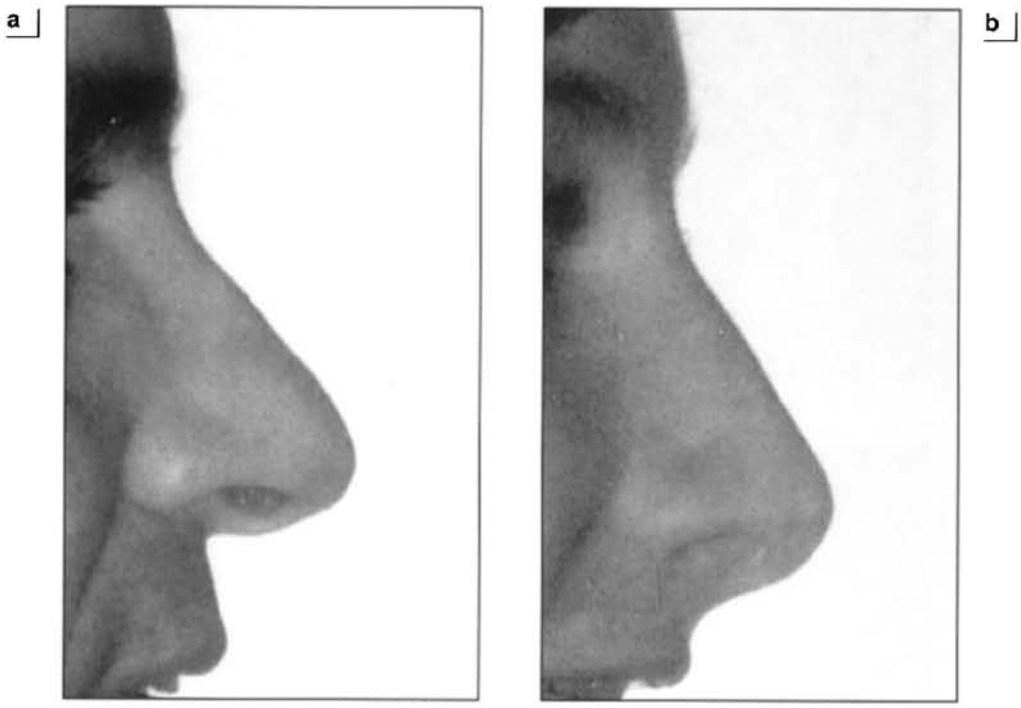


Fig 5-15 Two patients showing variation in the columellar cant and shape. Patient a is more horizontal than Patient b, resulting in a more-than-average acuteness in the nasolabial angle.

shape is common and variation in the columellar cant is acceptable. Note the pretreatment variation in nose morphology and columellar cant in the two patients shown in Fig 5-15. In Fig 5-15a, the nasolabial angle is more acute than average; this is related more to the columellar line than to a protrusive upper lip. The obtuse nasolabial angle in Fig 5-15b has both upper lip and columellar components.

The patient in Fig 5-16 presented with a Class II, division 1 malocclusion and was treated by retraction of the upper incisors; the resulting facial profile is esthetically compromised. Upper and lower lips were normal to the subnasale–pogonion line before treatment (Fig 5-16a) and posterior to this line after treatment (Fig 5-16b); the difference is illustrated in the before-after lip superposition (Fig 5-16c). The excessively obtuse nasolabial angle is also disturbing because it is the result of a posteriorly inclined lip.

The patient with a Class II, division 1 malocclusion shown in Fig 5-17 received treatment that involved removal of the upper first premolars and orthognathic surgery to set back the anterior segment of the maxilla. The effect is similar to that achieved by orthodontically retracting the upper incisors—that is, a retro-inclined upper lip and an excessively obtuse nasolabial angle. A better surgical option for reducing the overjet would have been to advance the mandible so as to reduce the total facial convexity while maintaining the original inclination of the upper lip without removing any teeth. Further details regarding soft tissue measurements and standards are included in the Appendix.

Until now only the average integumental profile has been discussed. While moving toward an average may be socially acceptable, it is important to recognize that all patients should not look alike at the end of treatment. However, several factors should be considered when varying a treatment goal from a standard.

The shape, form, and size of the nose can be an influencing factor. R. M. Ricketts described the plane from the tip of the nose to the chin as the esthetic plane and pointed out that as the nose

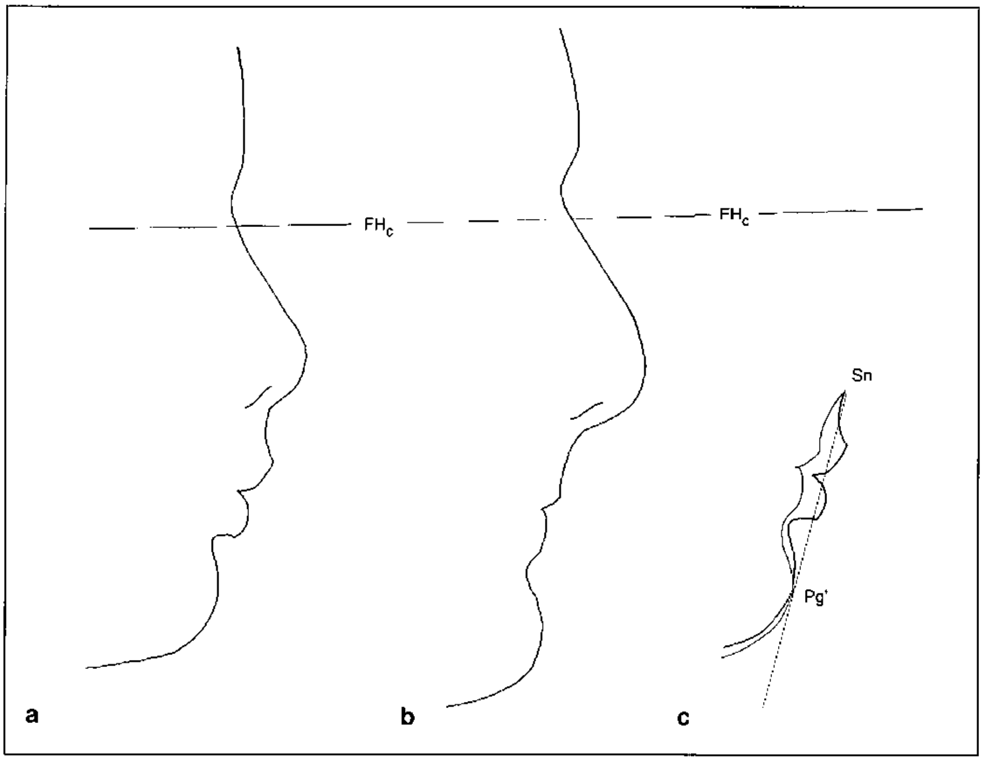


Fig 5-16 Retraction of the upper incisors for the correction of a Class II, division 1 malocclusion resulted in extreme lip retrusion. a, Before treatment. Lip protrusion (relative to the Sn–Pg' line) is normal. b, After treatment. Upper and lower lips are retrusive to the same line and a greater than average nasolabial angle is present. The retruded upper lip is responsible for the increased nasolabial angle. c, Before-after lip superposition.

becomes larger and more prominent, greater lip protrusion is acceptable. However, the nose is one of the most variable structures of the face. To offer an extreme example: if there were such a thing as a "Pinocchio nose," it would be unreasonable to protrude the lips so that they had a normal relationship to the esthetic plane (Fig 5-18). For this reason, the lip relationship to the subnasale–pogonion line is of primary interest and the shape, form, and size of the nose are considered only secondarily.

Another factor influencing lip protrusion is maxillary and mandibular sulcus depth. In adolescents, maxillary sulcus depth is 2 mm and mandibular sulcus depth is 4 mm. If a sulcus depth is small, more lip protrusion might be desirable; conversely, retrusion of the lips can improve a profile with excessive sulcus depth.

It could be argued that patients with greater than average facial convexity can afford a slightly greater than average lip protrusion to help "mask" the facial convexity. The same would be true with an excessively concave face: greater lip protrusion could help "mask" the concavity. It may also be desirable to increase the amount of lip protrusion as facial height increases so that, proportionally, the lips and face will appear normal.

Are gender differences in amount of lip protrusion considered desirable? Many studies have shown that average lip protrusion does not differ significantly between men and women. Nonetheless, a common perception—at least in some Western countries—is that more protrusive lips are desirable in women.

There are broad racial differences in the amount of lip protrusion considered desirable,

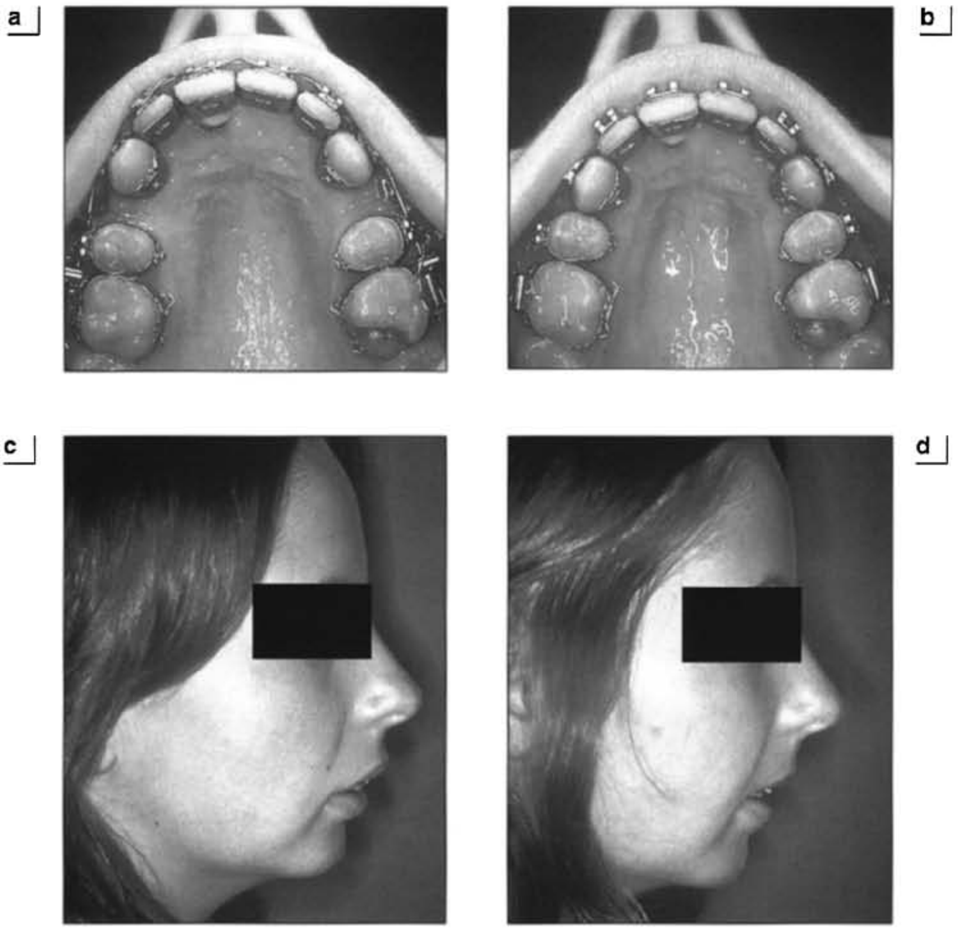


Fig 5-17 Class II, division 1 malocclusion treated by orthognathic surgery. An anterior maxillary osteotomy (setback) produced a result similar to that of orthodontic anterior retraction. a, Maxilla before surgery. b, Maxilla after surgery. c, Facial profile before treatment. d, Facial profile after treatment. The greater than average nasolabial angle was associated with a lingually inclined upper lip. A preferable plan would have been to surgically advance the mandible.

Fig 5-18 A reference plane for evaluating lip protrusion using the nose can be misleading. With a "Pinocchio" nose, for example, it would be unreasonable to protrude the lips to establish a normal relationship to the nose–soft tissue pogonion line. The large variation in nose size and form allows more freedom in lip positioning.

and this can present a problem in treatment. Some patients would prefer to have a facial profile that conforms more closely to the predominant racial or ethnic group in the community rather than to a standard or average.

When facial esthetics, including lip protrusion, is one of the objectives of treatment, an artistic value judgment must be made. This judgment cannot be made independently by the orthodontist, but requires input from the patient and the patient's family. Some facial standards are valid since what is typical often is esthetically desirable. But one should resist the temptation to make all orthodontic patients look alike. Some parents may not want their child's features to be altered to look more like those considered the norms of a given society. They may actually prefer to retain the slight differences in the faces of their children after treatment. Beauty is not achieved through statistical averages; an attractive face has curvatures and contours that go beyond measurements and standards, and different people have different perceptions of what is attractive.

Determining Incisor Position Based on Lip Protrusion

Anteroposterior incisor position is determined on the basis of facial esthetics, perioral function, and stability. How much lip protrusion is desirable must be established before one can determine the incisor position required to produce it.

To begin, the patient's facial profile before treatment should be evaluated using all available records, ie, the clinical examination, photographs, and the lateral headfilm. Next, the face itself should be studied with the lips in their relaxed rather than closed position so that the manner of lip closure and its associated musculature can be observed. In a patient requiring complete upper and lower dentures, different wax dentures can be tried and various lip protrusions can be measured and evaluated. Similarly, by mentally extracting the anterior teeth, the orthodontist can place the upper and lower lips in an ideal position, and then estimate where the upper incisors would have to be positioned to support this ideal lip protrusion. This process involves both art and science since the lips are dynamic muscular structures that are only complicated by growth.

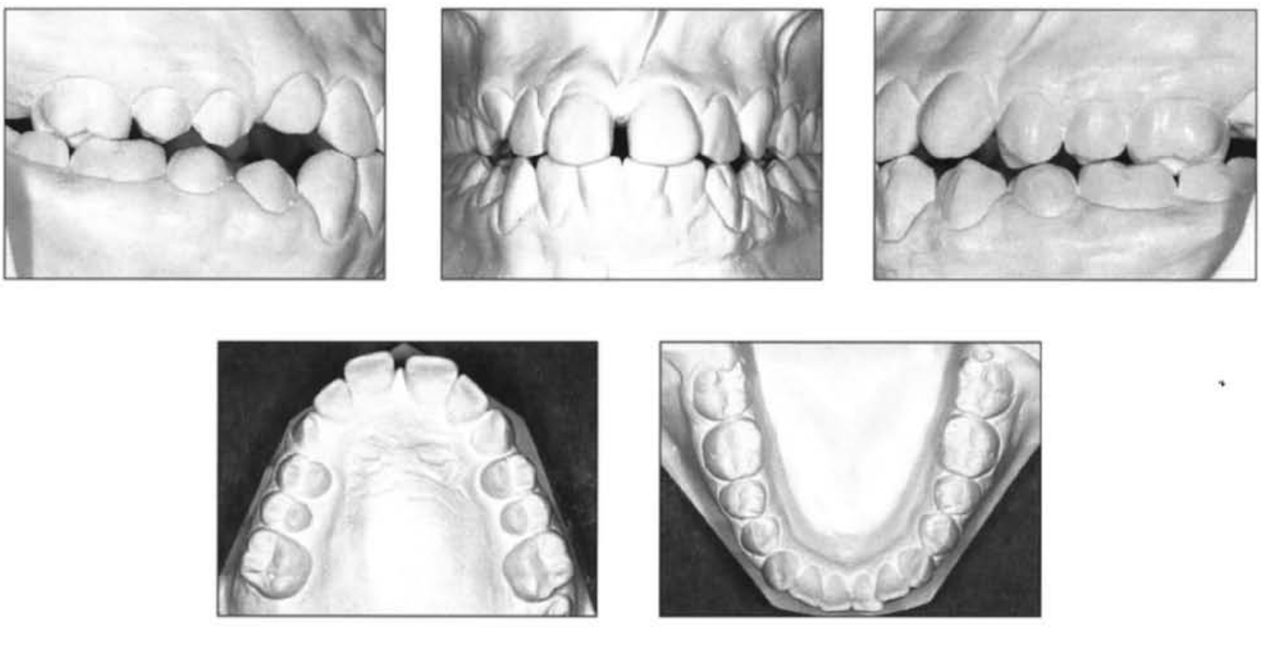
How accurately can one plan soft tissue changes based on hard tissue movement? A large variation is found between anteroposterior incisor position and changes in lip position. Typically, the lower lip mimics the lower incisor in a 1:1 ratio; that is, 1 mm of incisor retraction results in 1 mm of lip retraction. The upper lip and the upper incisor have a more variable relationship; on average, about 3 mm of incisor retraction is required for 1 mm of upper lip retraction. Greater variation is found in the relationship of the upper lip–upper incisor than in the lower lip–lower incisor.

Patient SS has protrusive lips, an asymmetrical occlusion in the posterior segments, and a lateral open bite (Fig 5-19). Four premolars were removed as part of her orthodontic treatment. Both the upper and lower lips retracted along with the incisors: her original lip protrusion was 4 mm/4 mm relative to the Sn–Pg' line; after treatment this was reduced to 2 mm/1 mm. Remodeling of the lower alveolar process is visible on the lateral headfilm and on the cast sections through the incisors. The retracted lips offer lingual restraint to the incisors, lending stability to their position. The lateral open bite did not recur. The before-treatment frontal facial photographs show the habitual relaxed posture of the lips and the strain needed for lip closure. After treatment, the habitual posture of the lips was lips together, which increased the stability of the retracted incisors.

Fig 5-19 Patient SS exhibited bimaxillary lip protrusion. a, The habitual lip posture is lips apart, and perioral strain is required to effect lip closure. b, Dental casts before treatment. c, Dental casts after treatment. d, Sections cut through the lower incisors show alveolar remodeling after retraction. e, Cephalometric superpositions. The retraction of the incisors improved both her lip protrusion and the manner of her lip closure, allowing her to assume a habitual posture of lips together. f, Subnasale–soft tissue pogonion superposition showing the lip relationship to the Sn–Pg' line before and after treatment.

a

b



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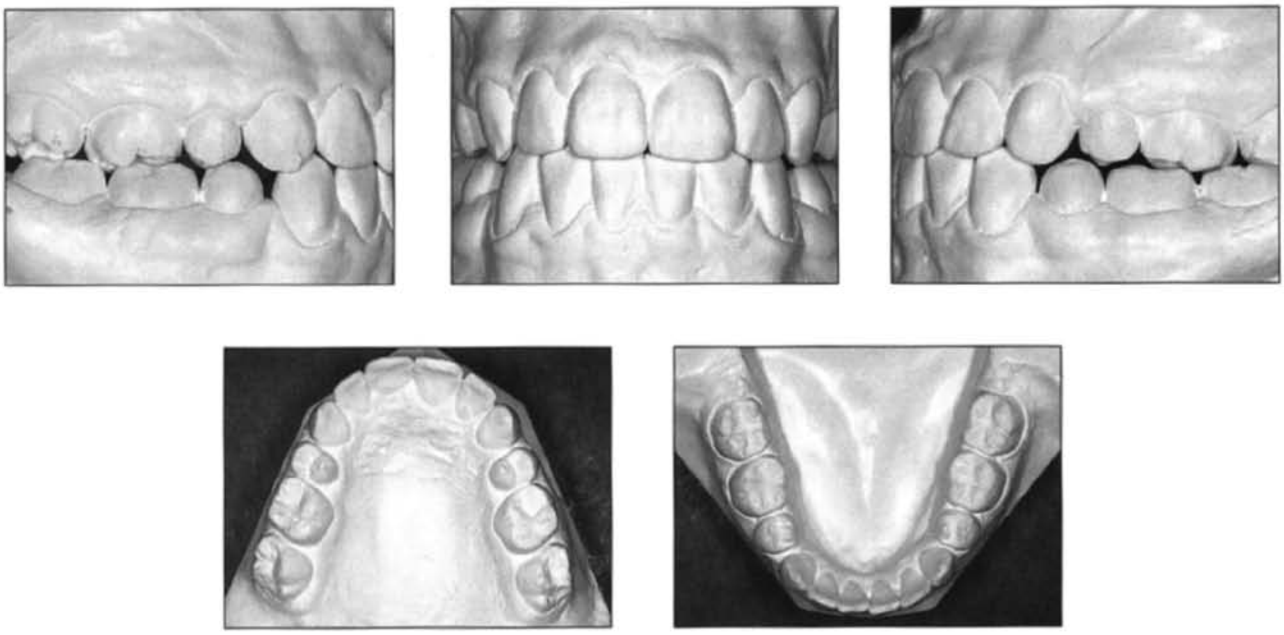

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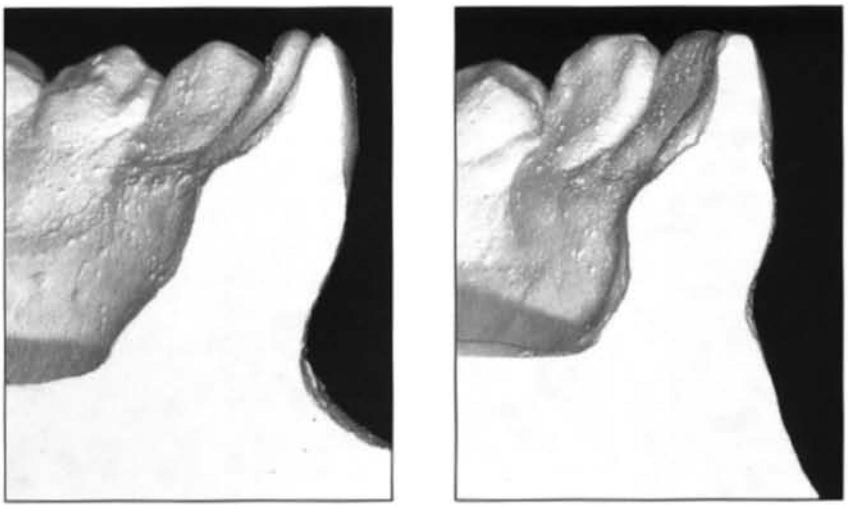

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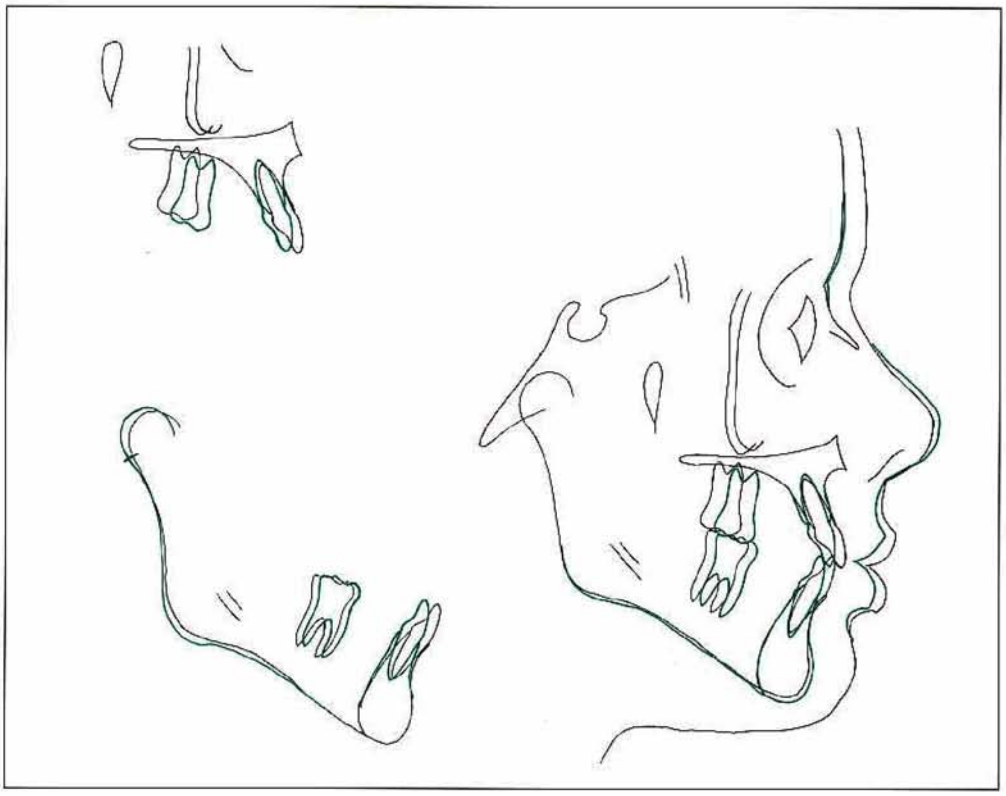

— original position — treatment outcome

f

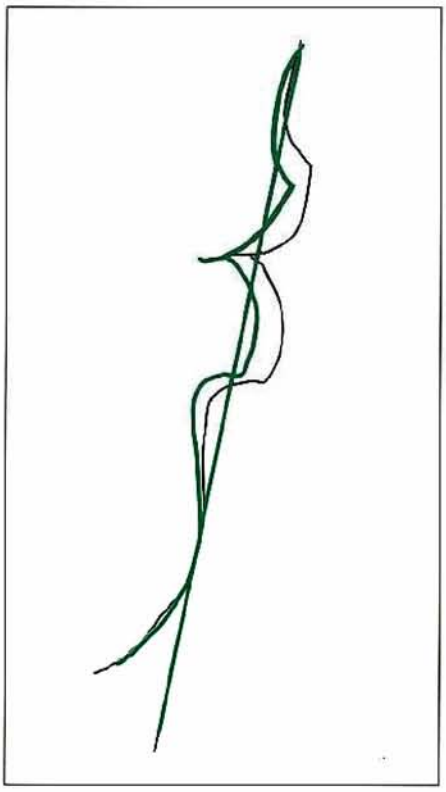

Fig 5-20 Patient LF had her lower incisors advanced to improve her lip protrusion. a, Facial photographs before and after treatment. b, Study casts before treatment. c, Study casts after treatment. d, Sections through upper and lower incisors, before and after treatment. e, Sections cut through the lower incisors show the incisor advancement along with alveolar remodeling. f, Cephalometric superpositions. g, Subnasale–soft tissue pogonion superposition showing changes in lip protrusion.

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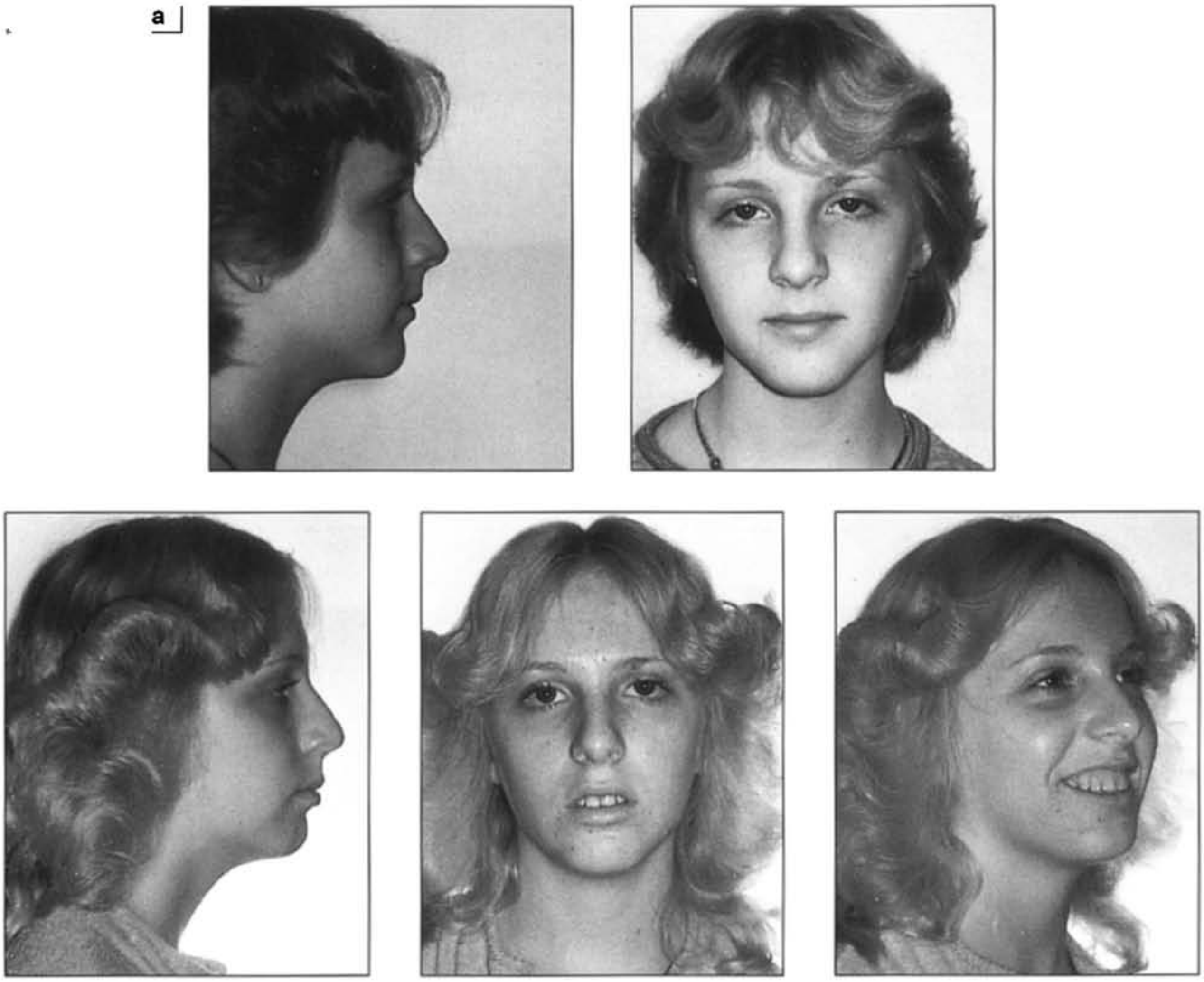
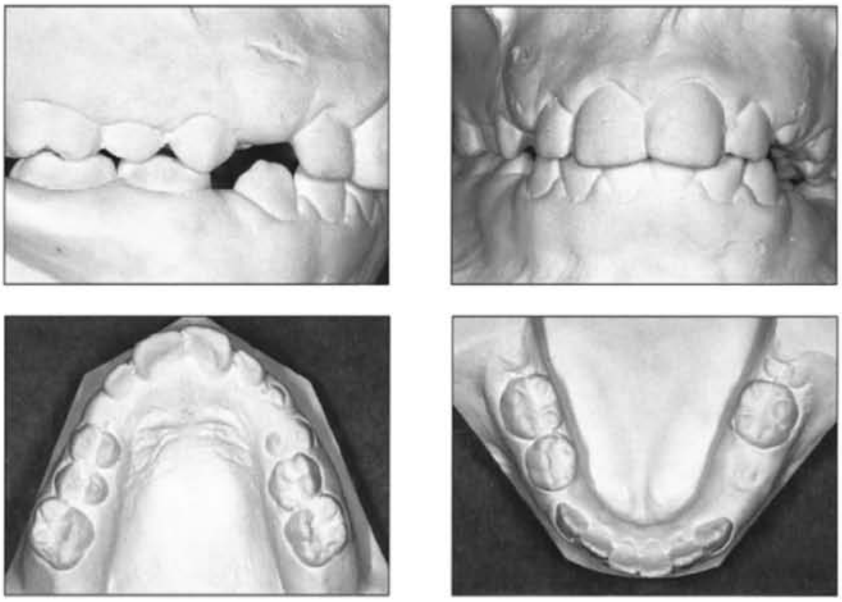


Patient LF presented with a Class I molar relationship with overjet and a moderate mandibular arch length inadequacy (Fig 5-20). Her lips were less protrusive than average (2 mm/1 mm) relative to the Sn–Pg' line. After considering the options, the esthetic treatment of choice was to advance the incisors so as to increase her lip protrusion relative to the Sn–Pg' line (5 mm/5 mm). Although that may seem excessive, the facial esthetics are pleasing; her lips followed the incisor advancement to a proportional degree. Other changes were produced by the skeletal and soft tissue growth. The cast sections through the lower incisors show the remodeling of the alveolar process as the lower incisors were advanced.

Patient BF, who presented with a Class I malocclusion and slight crowding, was initially treated without removing any teeth (Fig 5-21). However, as her incisors were advanced, the increased lip protrusion that resulted, with her lower lip protruding more than her upper lip, was judged to be

b



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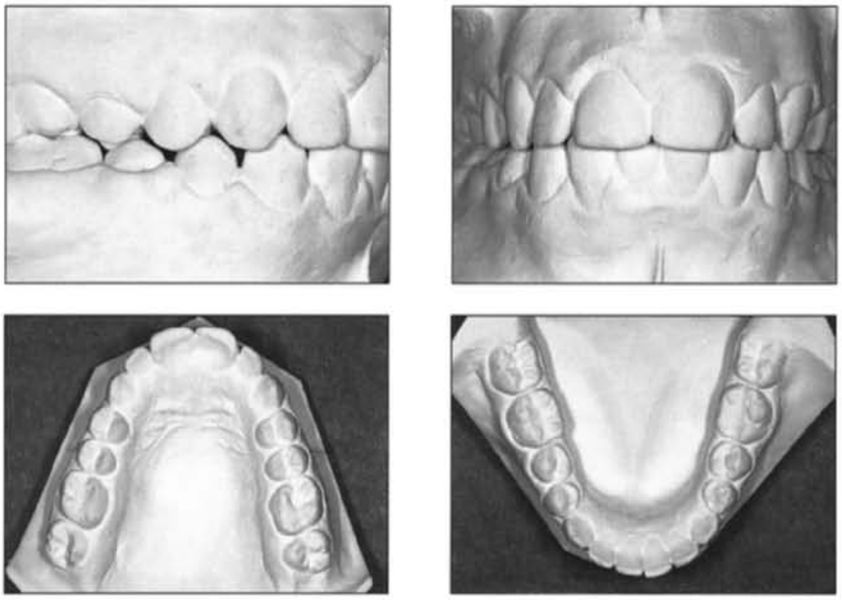

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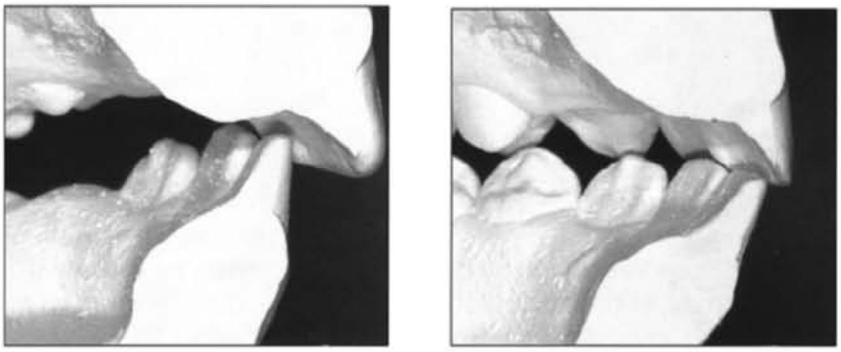

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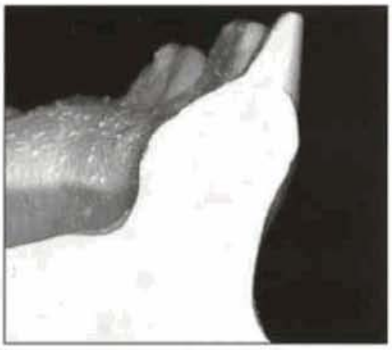

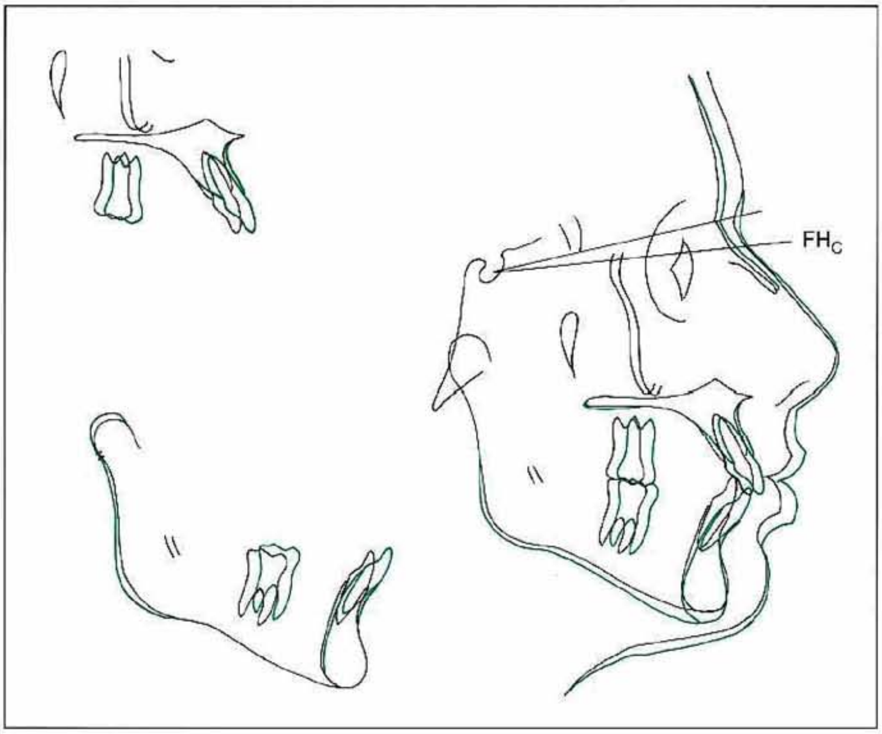

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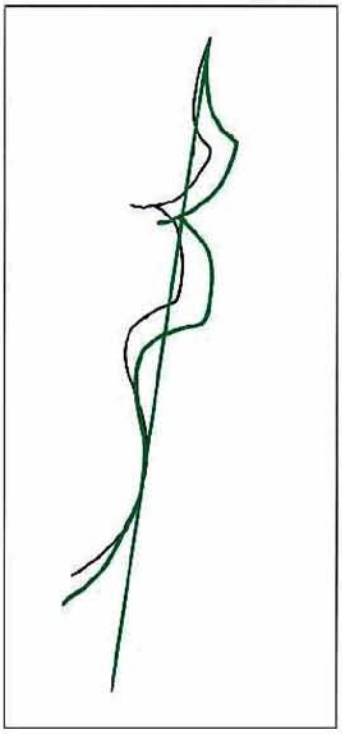


g

— original position — treatment outcome

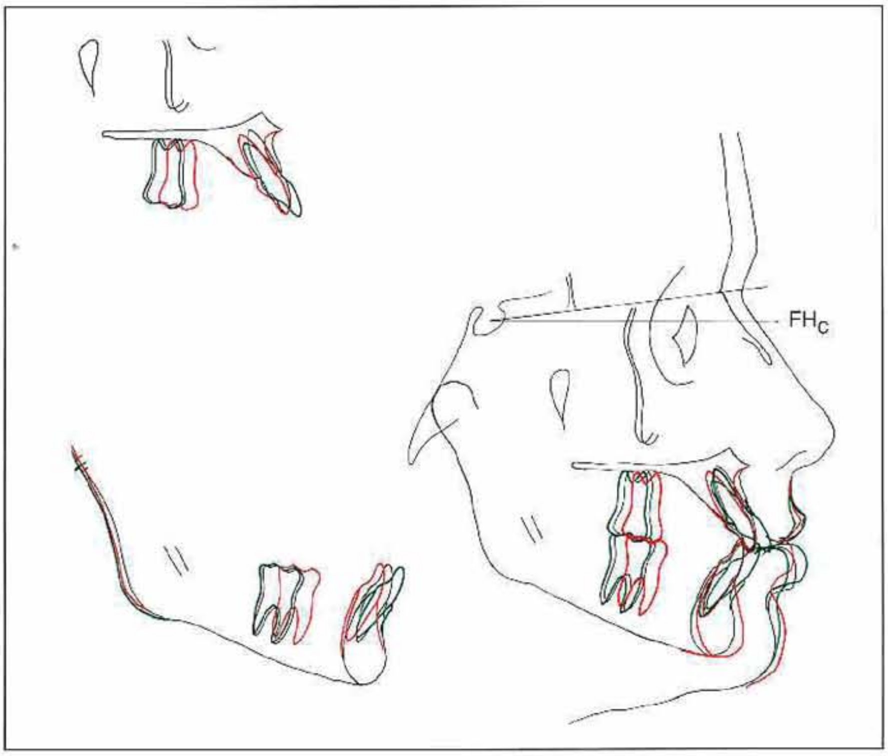
esthetically unappealing. To reduce her lip protrusion, a decision was made to remove the four first premolars. Following treatment, the lower incisors were lingual to their original position and the upper incisors were maintained in their original position. Greater incisor retraction was required in the mandible than in the maxilla to compensate for their different amounts of anteroposterior growth. (This point is addressed in more detail below.) Final lip protrusion is slightly less than it was before treatment, but close to average. When the incisors were advanced as well as when they were retracted, the relationship of the lower lip to the lower incisor was almost 1:1; that is, the effect was greater on the lower lip than on the upper lip.

Fig 5-21 Patient BF shows a moderate arch length inadequacy. Initially, a desire for increased lip protrusion precluded the removal of any teeth. As treatment progressed, the increase in lip protrusion was deemed unesthetic and the treatment plan was revised to reduce the lip protrusion by removing four first premolars. This allowed for greater stability and a more normal lip protrusion. a, Before- and after-treatment occlusion. b, Before-treatment photographs. c, After-treatment photographs. d, Cephalometric superpositioning before and after advancing the incisors with the accompanying changes in lip protrusion. Black, before treatment; green, after flaring of the incisors; red, final outcome. e, Lip profile in d superposed on the Sn-Pg' line. Black, before treatment; green, after flaring of the incisors; red, after extraction of four premolars.

a

b

c



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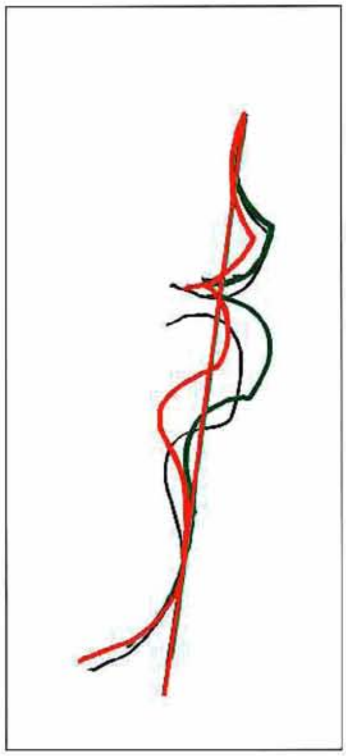

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The preceding cases illustrate how lip protrusion can be fairly accurately predicted on the basis of incisor position. Factors that can decrease predictability include difficulty in visualizing the profile from either a photograph or a lateral headfilm tracing, lack of differentiation in the tracings between midline or lateral structures in the lips, or slight rotation of the head, giving a somewhat different projection.

Unlike hard tissues, the lips and the soft tissue chin contours are influenced by muscle contraction. The manner in which a patient postures the lips when a headfilm is exposed can significantly influence the lip and soft tissue chin thicknesses and overall contours. For this reason, lateral cephalometric headfilms are most useful diagnostically when they are made with the teeth in occlusion but with the lips in a relaxed posture. From this posture the clinician can more accurately measure the soft tissue thickness at the base of the nose, the upper and lower lips, and the chin. During the clinical examination, the clinician measures how much the lips protrude when lightly touching and notes the manner of lip closure—whether they close primarily by the lower lip moving up, the upper lip moving down, or equal proportions of both.

For patients with large interlabial gaps, the orbicularis oris muscle complex must contract in order for them to close their lips; this contraction effectively thins the lips and results in a greater than expected reduction in lip protrusion.

Patient AB presented with a Class I malocclusion with moderate overjet, protrusive lips, and an excessively large interlabial gap (Fig 5-22). Moreover, mentalis muscle contraction was required to achieve lip closure, as illustrated in the original facial photographs (Fig 5-22a). During

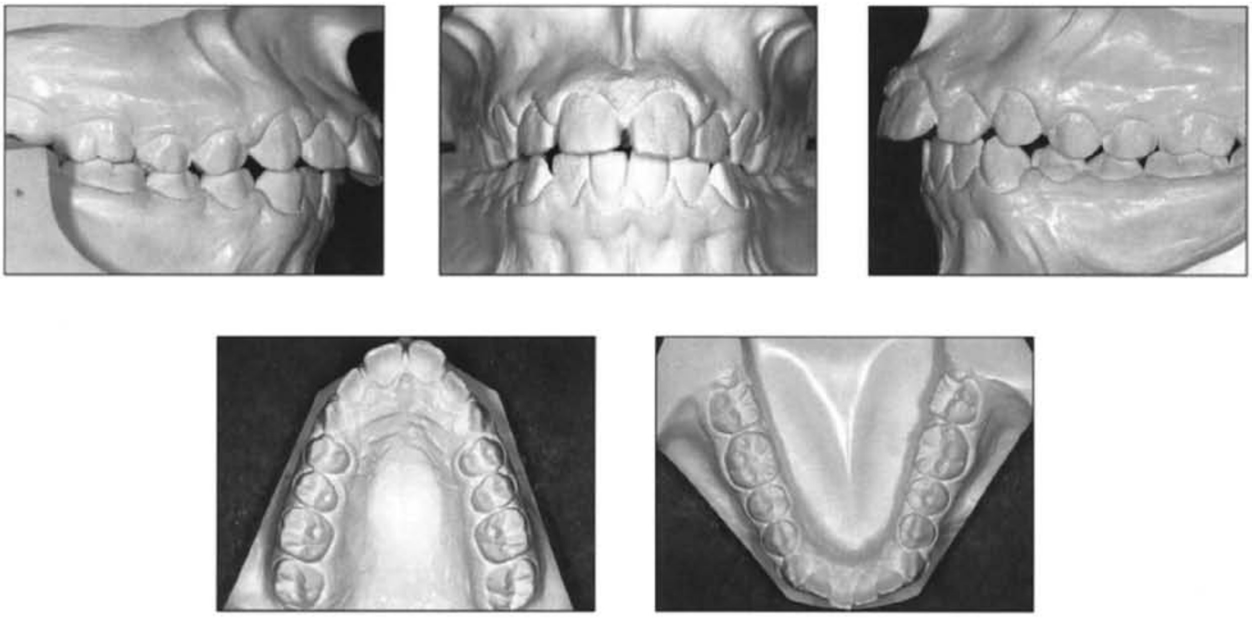
Fig 5-22 Patient AB presented with an excessive interlabial gap. Soft tissue profile changes have not been achieved by incisor retraction. Nose growth and an alteration of muscle function during lip closure are equally responsible. a, Facial photographs before treatment. b, Facial photographs after treatment. c, Study casts before treatment. d, Study casts after treatment. e, Cephalometric superpositions. f, Subnasale–soft tissue pogonion superpositions.

a

b

treatment both the upper incisors and the upper lip were retracted. Following incisor retraction the upper lip often seems to thicken. In this patient the upper lip appeared to thin; that is, the muscle contracted. Many factors, such as nose growth, a change in the position of subnasale, and soft tissue recontouring of the chin owing to the elimination of the mentalis muscle contraction, may have contributed toward a reduction in lip protrusion. (More retraction of the incisors would have been desirable to further reduce the lip protrusion; however, this requires extraction.)

c



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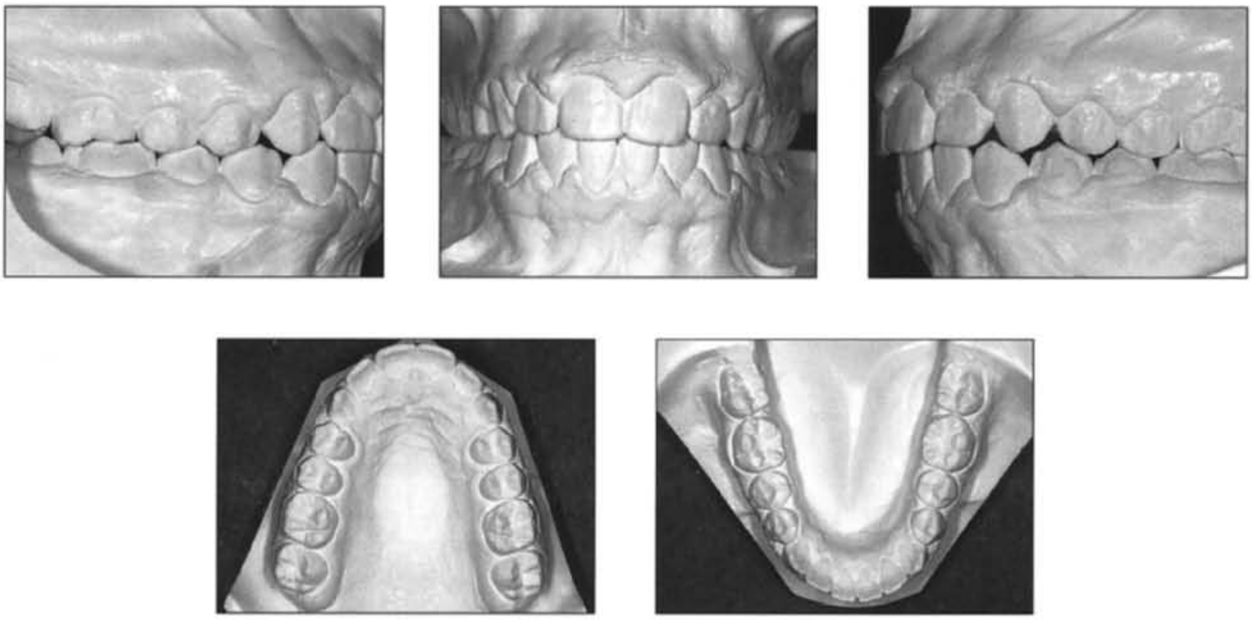

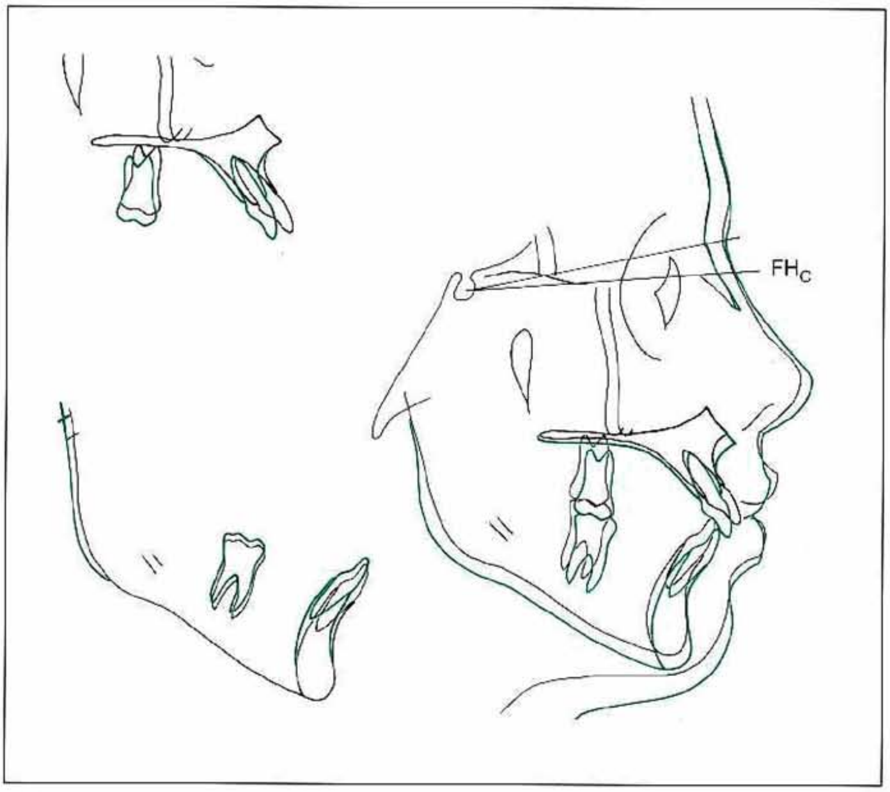

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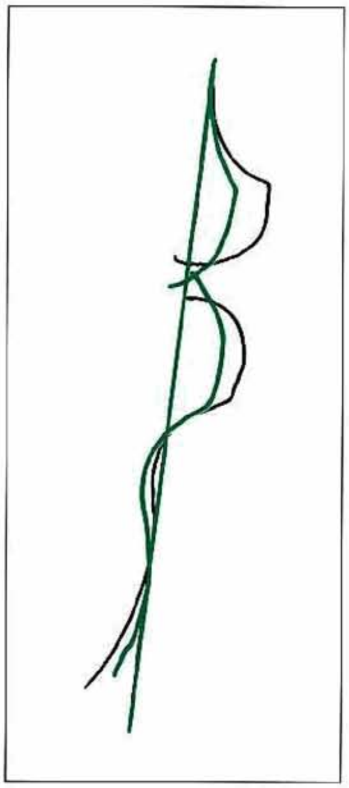


f

— original position — treatment outcome

In patients with excessive lip length—that is, lip length redundancy—lips support each other and project anteriorly to the teeth. In these patients, lip retraction does not follow incisor retraction unless vertical dimension of the face is increased.

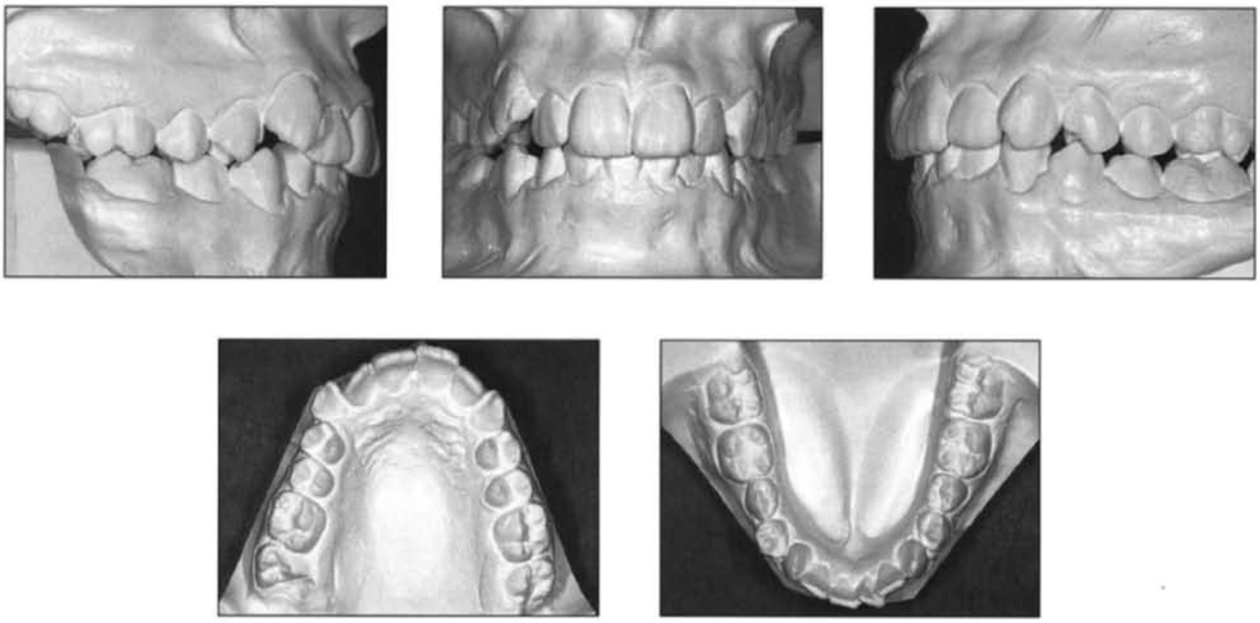
As we saw above, when lip protrusion is evaluated to the Sn–Pg' line, any change in chin thickness will influence the effective lip protrusion. Both head posture and contraction of the mentalis muscle can alter the soft tissue contours of the chin.

Many patients with protruding incisors and, in particular, an excessive overjet not only displace the upper lip labially, but display a thinner upper lip as a result of pressure from the upper incisor. As the incisors are retracted, the upper lip increases in thickness. This explains why upper lip retraction does not always share a 1:1 relationship with upper incisor retraction.

Patient CN presented with a Class I malocclusion with crowding (Fig 5-23) and was treated by having four premolars removed. The left buccal segment was an end-to-end Class II, which required asymmetrical mechanics during space closure. Despite the incisor retraction, the before- and after-treatment lip protrusions are almost identical. At the beginning of treatment, the upper incisor compressed the upper lip, which subsequently thickened following incisor retraction.

Fig 5-23 Patient CN was treated by the extraction of four premolars. Although the incisors were retracted, there was little change in the resulting lip protrusion. Thickening of the upper lip occurred during treatment. Note the initial compression of the upper incisor into the upper lip. a, Study casts before treatment. b, Study casts after treatment. c, Cephalometric superpositions. d, Subnasale–soft tissue pogonion superpositions.

a



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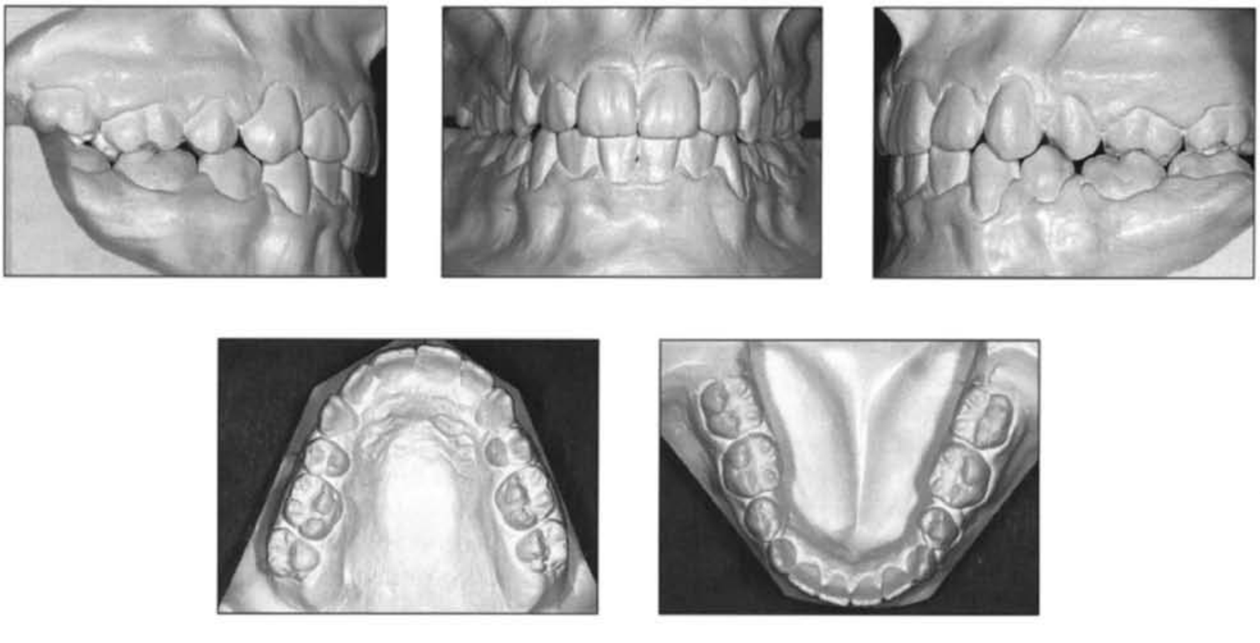

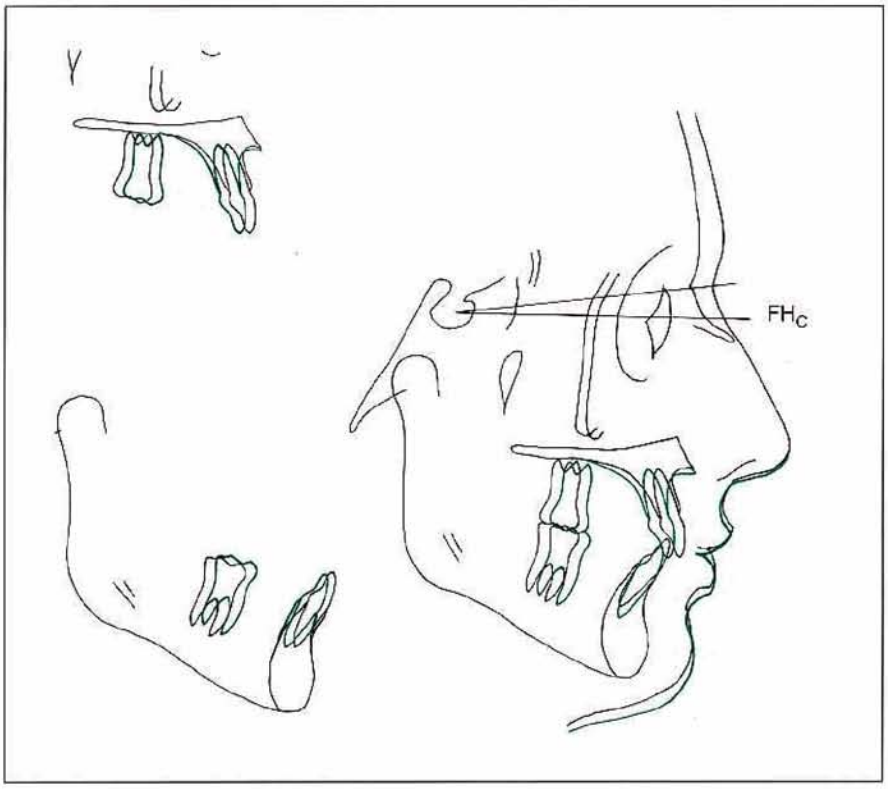

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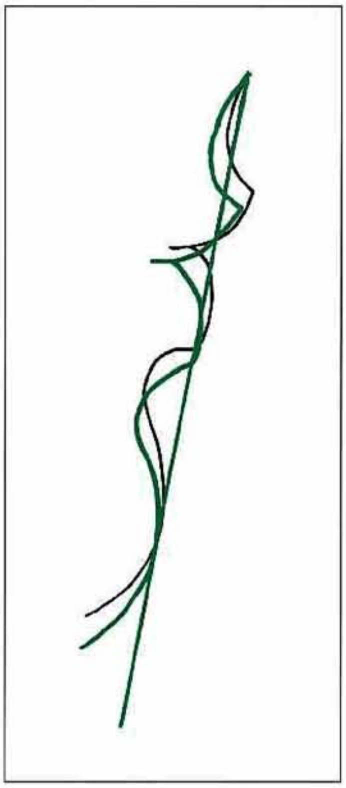


d

— original position — treatment outcome

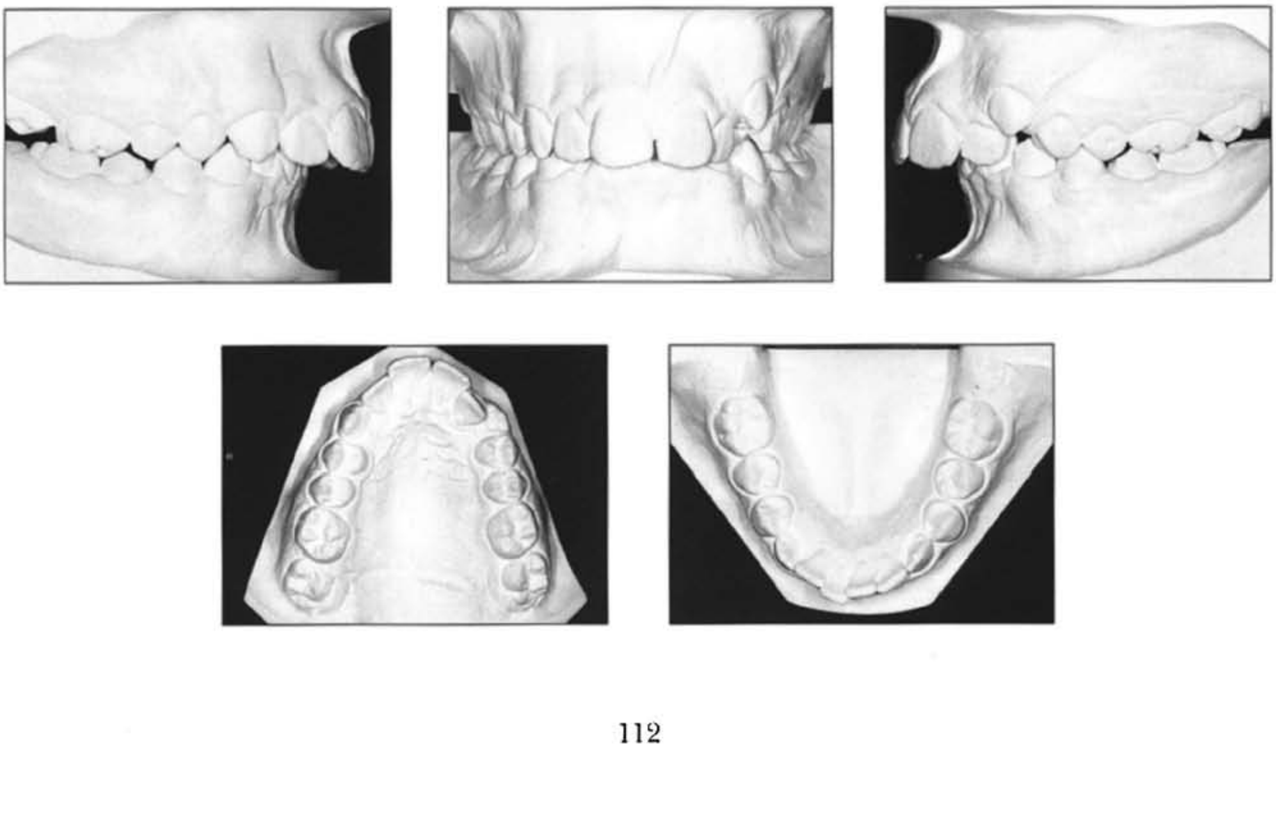
Patient DR exhibited a Class II malocclusion with an excessive overjet (Fig 5-24). The upper incisor was clearly pressed into the upper lip. Following incisor retraction, the thickness of the upper lip increased markedly, and hence the upper lip does not fall back as much as one would expect. The curl in the lower lip was reduced by means of elimination of the overjet and increase in the vertical dimension, causing the soft tissue chin to drop inferiorly.

Fig 5-24 Patient DR experienced a marked increase in the thickness of his upper lip during treatment, resulting in less upper lip retraction than expected. The curl of the lower lip has been reduced by elimination of the overjet and an increase in the vertical dimension of the lower face. a, Before-treatment facial profile photograph. b, After-treatment profile photograph. c, Study casts before treatment. d, Study casts after treatment. e, Cephalometric superpositions. f, Subnasale–soft tissue pogonion superposition.

a

b

c



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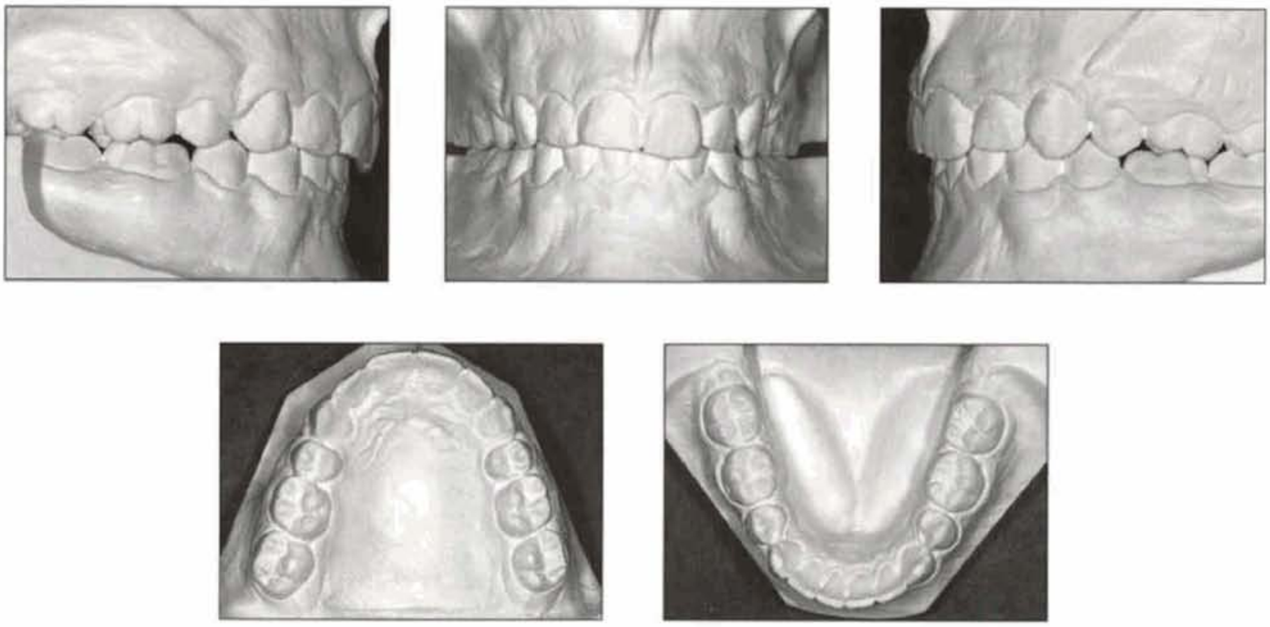

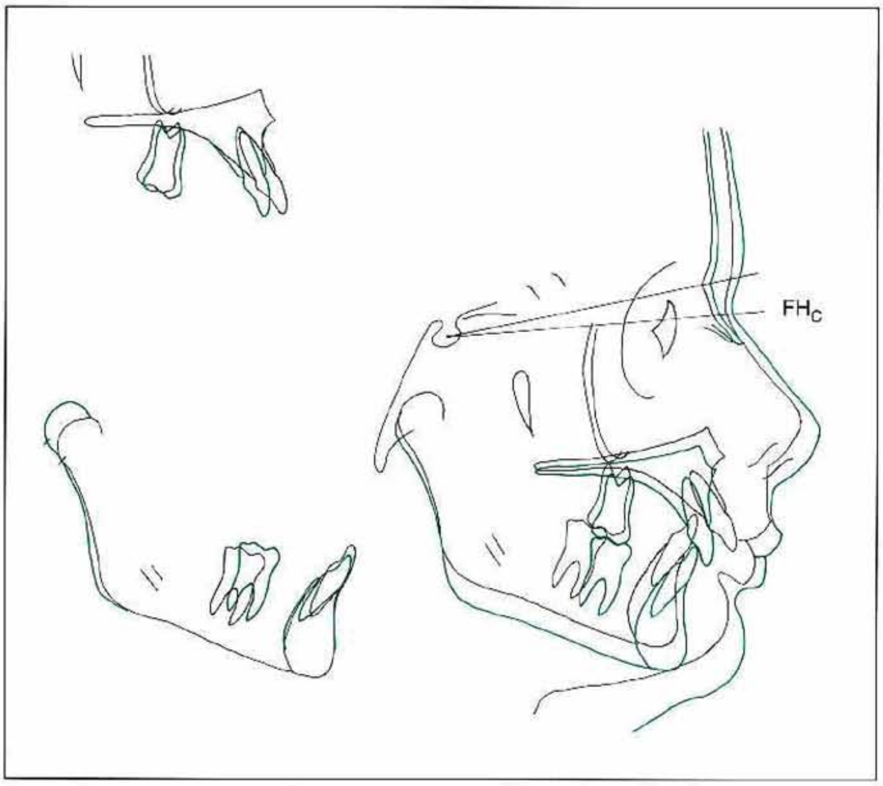

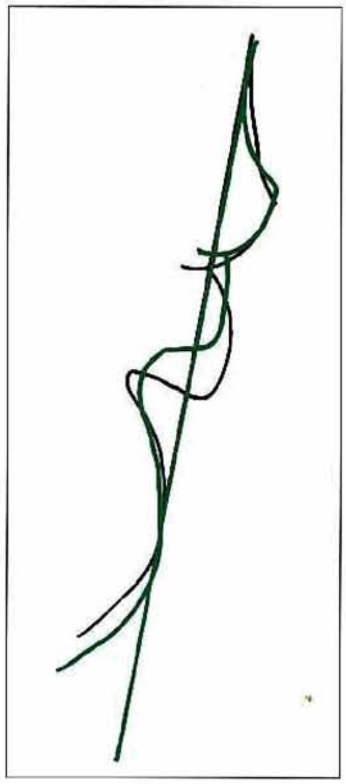

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f

— original position — treatment outcome

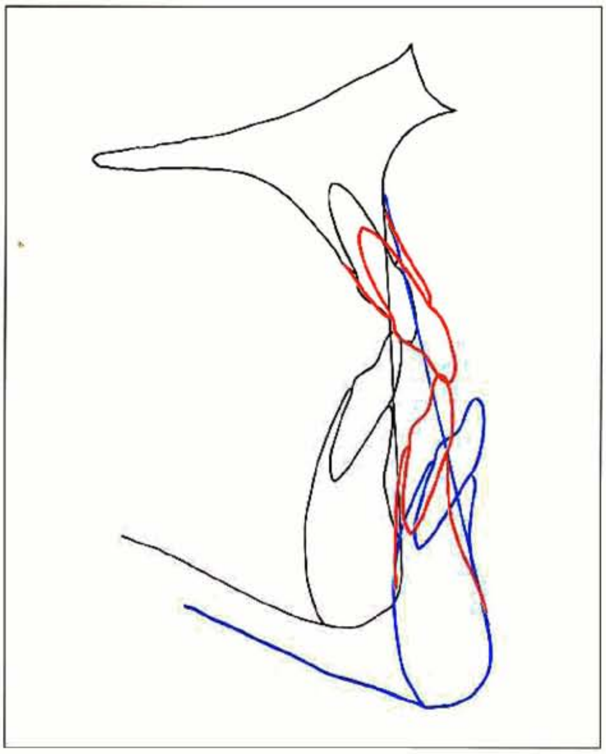

Fig 5-25 Differential growth between the maxilla and the mandible requires compensation in the position of the incisors. To maintain the lower incisor in the same relationship to an arbitrary line such as the point A-pogonion line, the lower incisor must be retracted approximately one half the amount of differential growth between the maxilla and the mandible.

Another important factor that influences the amount of lip protrusion is the differential growth between the maxilla and the mandible. How is this growth incorporated into the prediction of lip protrusion? Figure 5-25 shows a patient who has a pleasing face. At the beginning of treatment, the lower incisor is approximately on the point A-pogonion line. What if, over 2 years or more, this patient experiences considerably more mandibular than maxillary growth in a forward direction (which is quite typical)? If the teeth were ankylosed in place, a Class III malocclusion with underjet would result. (In Fig 5-25, the growth differential has been exaggerated for emphasis.) According to cephalometric standards, this does not happen because the lower incisors upright with age. Part of this uprighting could be related to upward and forward growth rotation of the mandible, the most typical type of growth pattern. As we age, our lower incisors tend to maintain their relationship to the point A-pogonion line. Therefore, if the same facial profile is to be maintained, the lower incisor must be moved lingually, back to the point A-pogonion line. This change is estimated in the procedure for establishing incisor position by taking the differential in maxillary and mandibular growth relative to the occlusal plane (the A-B[OP] difference) and dividing by 2. Note that in Fig 5-25 the upper incisor is positioned forward by one half of the A-B change and the lower incisor is retracted by one half of the A-B change. This compensation of the incisors preserves their pretreatment relationship with the A-Pg line.

Thus, in a Class II patient, where precocious mandibular growth might correct the Class II, greater lower incisor retraction and less upper incisor retraction are required to produce the same amount of lip protrusion relative to Sn-Pg'. This reinforces the importance of trying to estimate the growth potential of our patients, in spite of all the unknowns.

Patient LS showed marked lip protrusion (Fig 5-26). Four premolars were removed and the upper and lower incisors were retracted. Because of the differential in growth between the maxilla and the mandible, the mandibular incisors required more retraction than the maxillary incisors. The nose grew, carrying subnasale forward, and mandibular growth advanced the soft tissue chin beyond

Fig 5-26 Patient LS showed differential growth between the maxilla and the mandible. Because of this differential growth, the lower incisors required more retraction than the upper incisors. a, Facial photographs before treatment. b, Facial photographs after treatment. c, Study casts before treatment. d, Study casts after treatment. e, Cephalometric superpositions. f, Subnasale–soft tissue pogonion superposition.

a

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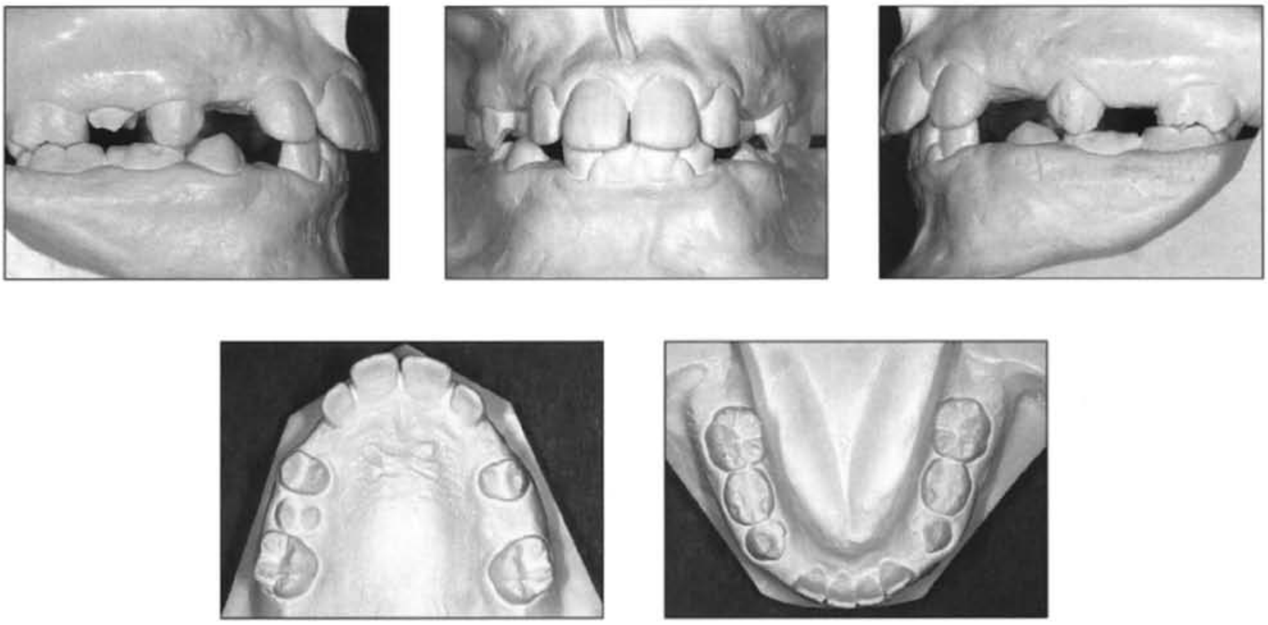

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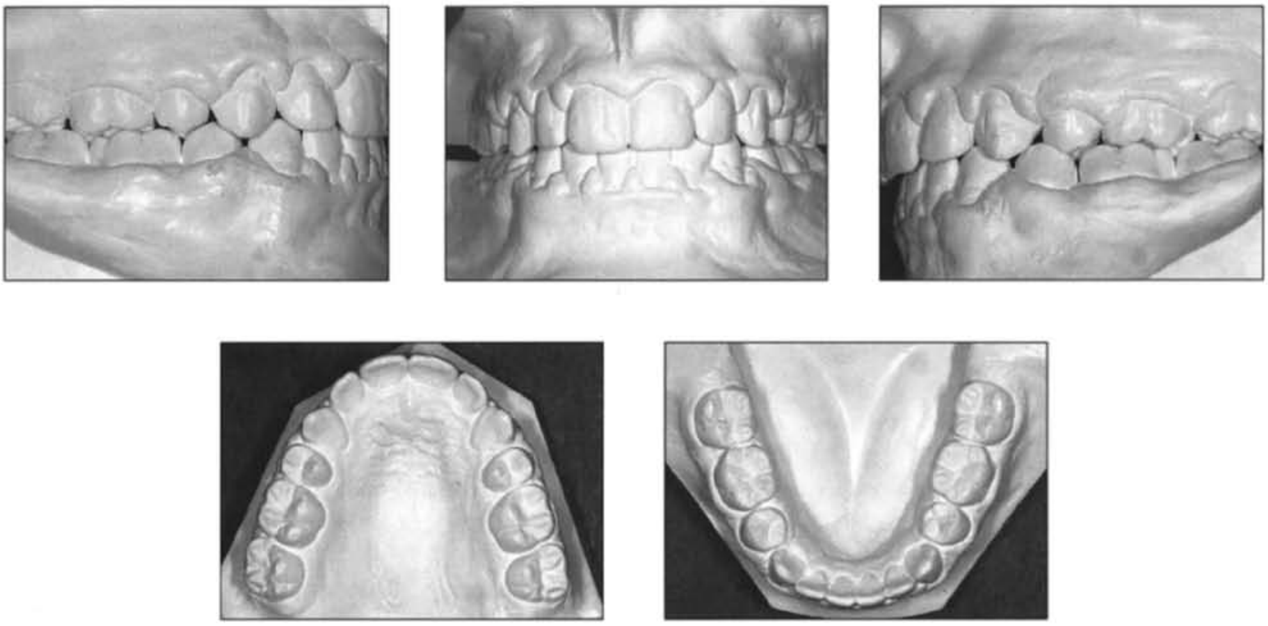

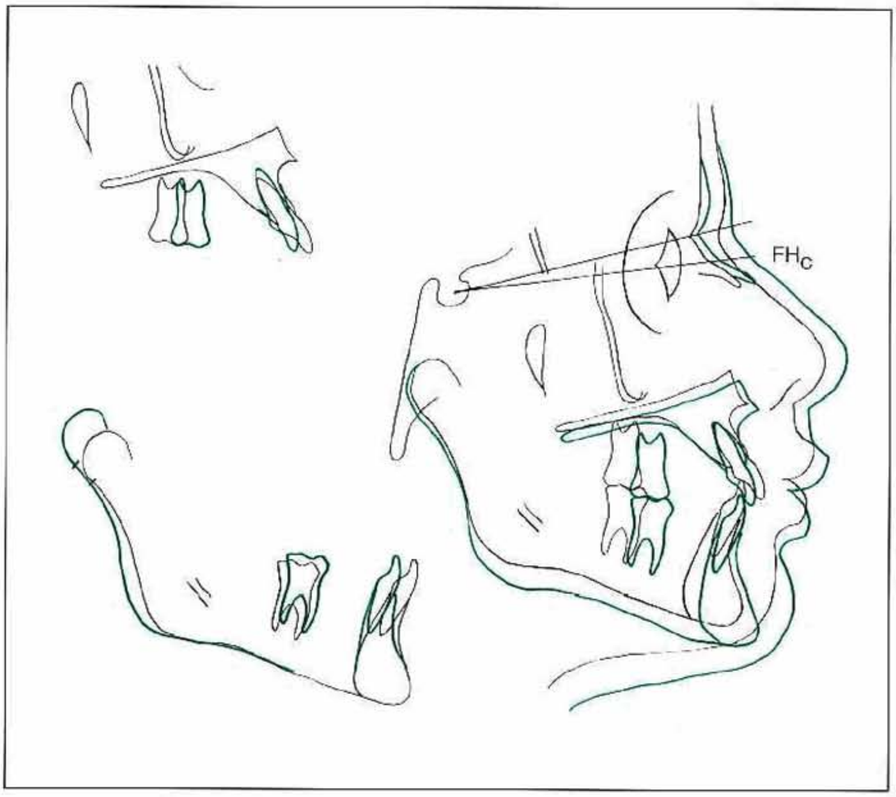

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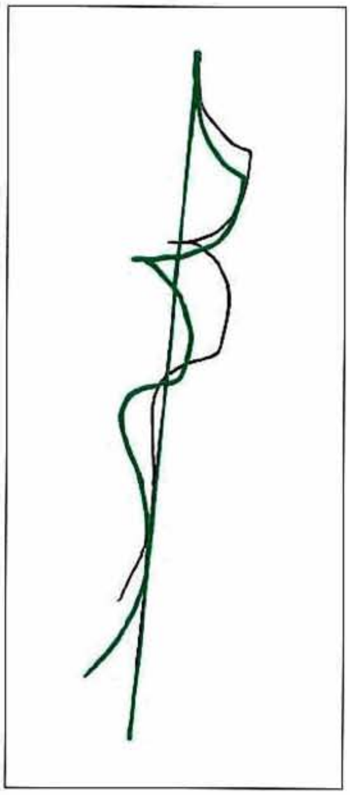

f

— original position — treatment outcome

subnasale, resulting in a reduction of the overall convexity of the face. Relative to the Sn–Pg' line, the lower lip retracted while the upper lip thickened and did not retract. It is not unusual for the lower lip to retract more than the upper lip. The favorable facial change is a result of both skeletal growth and incisor retraction.

Patient WC showed significant differential growth between the maxilla and the mandible, requiring differential placement of the upper and lower incisors (Fig 5-27). The upper incisors were flared while the lower incisors were minimally retracted, reducing the muscular pressure exerted by the lips during precocious mandibular growth. The flaring often seen with leveling was avoided. Lip protrusion to the Sn–Pg' line has been reduced slightly by the treatment even though the lower incisors are further forward of the A–Pg line. The change in the Sn–Pg' line is the collective result of differential skeletal growth, the forward movement of the soft tissue chin, and an increase in the thickness of the soft tissue chin. Because of this change, the lips do not appear to protrude despite the incisor position. Soft tissue responses to growth differ from skeletal responses. Subnasale descended beyond the descent of the anterior nasal spine, increasing upper lip length and in turn decreasing the amount of upper incisor displayed following treatment.

Positioning of the incisors for optimal facial esthetics involves two steps: (1) determining the optimal lip protrusion of a patient; and (2) determining the correct incisor position to produce this lip protrusion. Treatment planning is best done on the before-treatment face of the patient and should be based on the before-treatment soft tissue profile rather than on some hard tissue standard. Determination of incisor position is complicated by the many factors discussed above and requires consideration of both hard and soft tissue structures, muscle dynamics, and growth.

Fig 5-27 Patient WC showed significant differential growth between the maxilla and the mandible. Differential incisor movement—that is, flaring of the upper incisors and retraction of the lower incisors—was required. The altered Sn–Pg' line influences lip appearance. a, Facial photographs before treatment. b, Facial photographs after treatment. c, Study casts before treatment. d, Study casts after treatment. e, Cephalometric superpositions. f, Subnasale–soft tissue pogonion superposition. Note that there is little change in lip protrusion to this line even though the upper incisors were flared.

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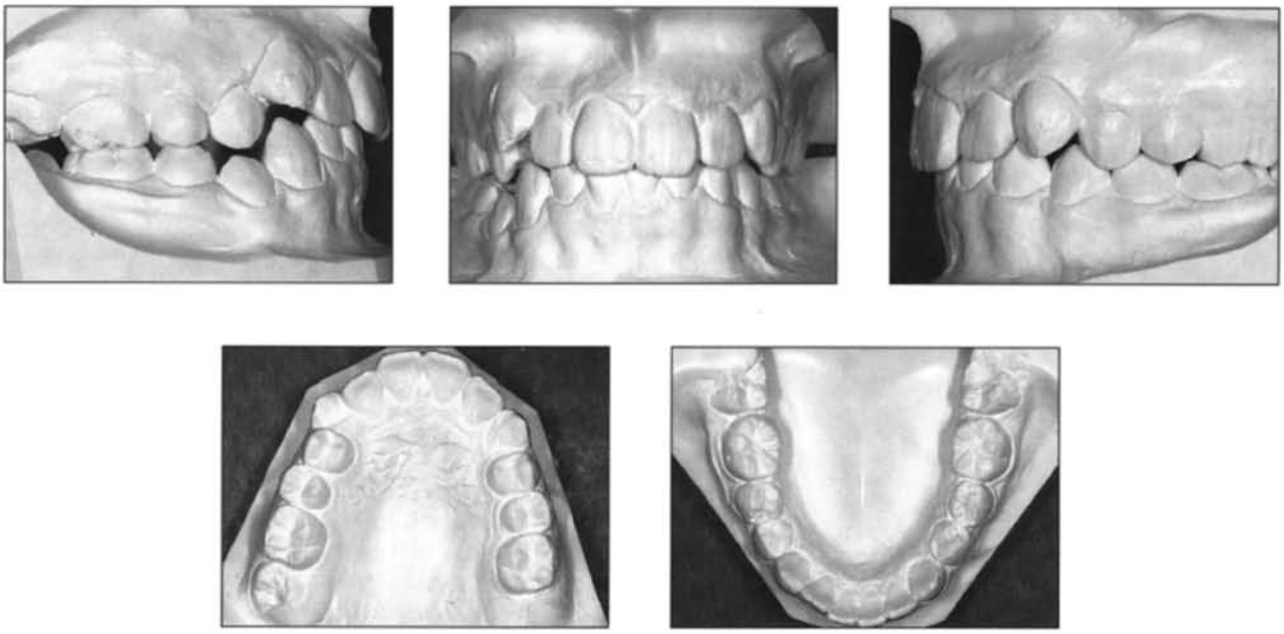

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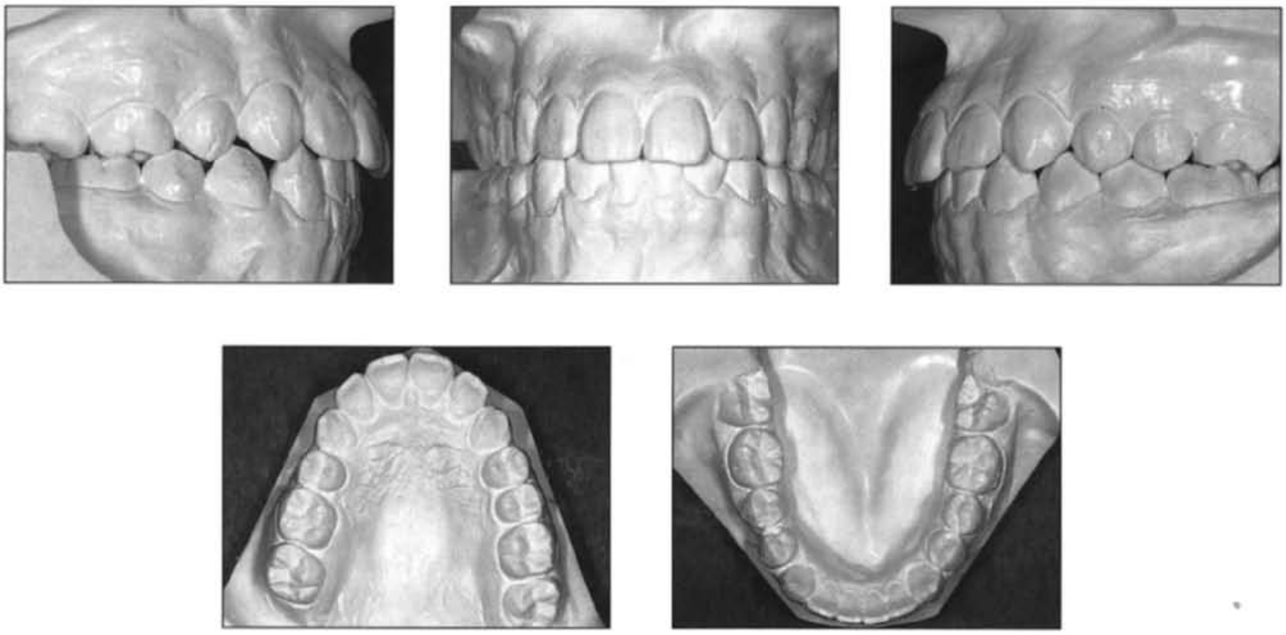

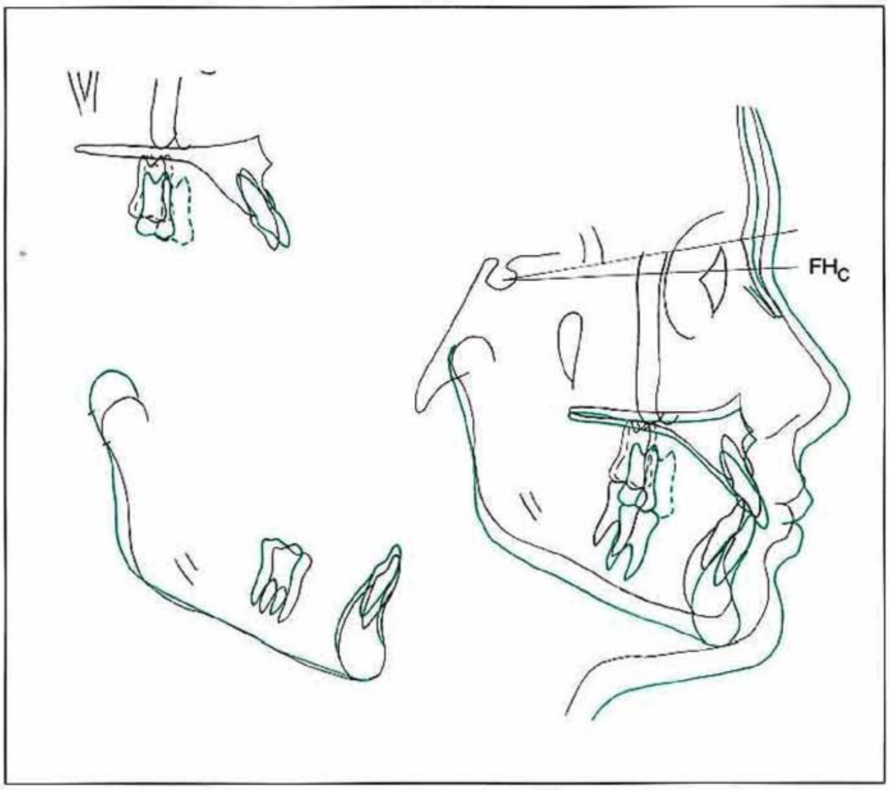

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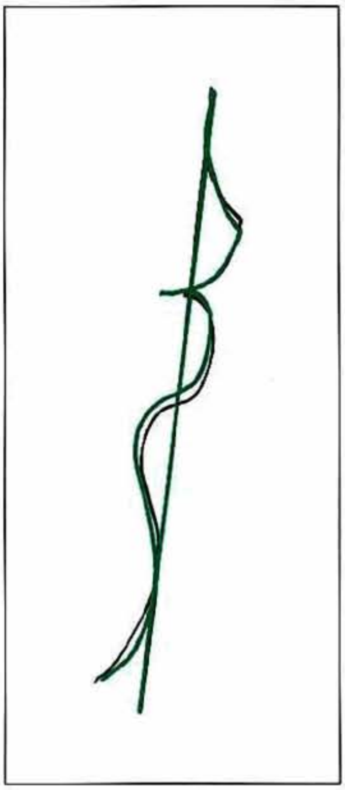


f

— original position — treatment outcome

Until now, only one factor—lip protrusion—has been considered for determining the A–P position of the incisors. Two additional factors must be considered before the desired incisor position can be established: perioral function and stability.

Anteroposterior Position of the Incisors Based on Perioral Function

Some patients have larger than average interlabial gaps (the average is about 2 mm). It is difficult for these patients to close their lips, and consequently they often have an open-lip posture. One of the goals of orthodontic treatment is to ensure that patients can easily close their lips, which requires an average interlabial gap. Surgery or mechanotherapy may not always be feasible options for reducing vertical dimension. For some patients with large interlabial gaps, the only option available is retraction of teeth. Figure 5-28 shows a patient who has an excessive interlabial gap that should ideally be treated with orthognathic surgery. However, an orthodontic compromise is to retract the incisors to facilitate lip closure; that is, as the lips fall back and lengthen, the perioral function of lip closure is improved.

Although greater than average effort may be required for lip closure, facial esthetics overall and lip protrusion in particular may be improved by retruding the incisors since the orbicularis oris proper rather than the mentalis muscle is contracted. When the upper incisors are protrusive, contraction of the mentalis muscle wrinkles the chin and protrudes the lower lip while the thinner soft tissue chin increases the facial convexity (Fig 5-29). A problem with retracting the incisors to improve perioral function can be retrusive lips.

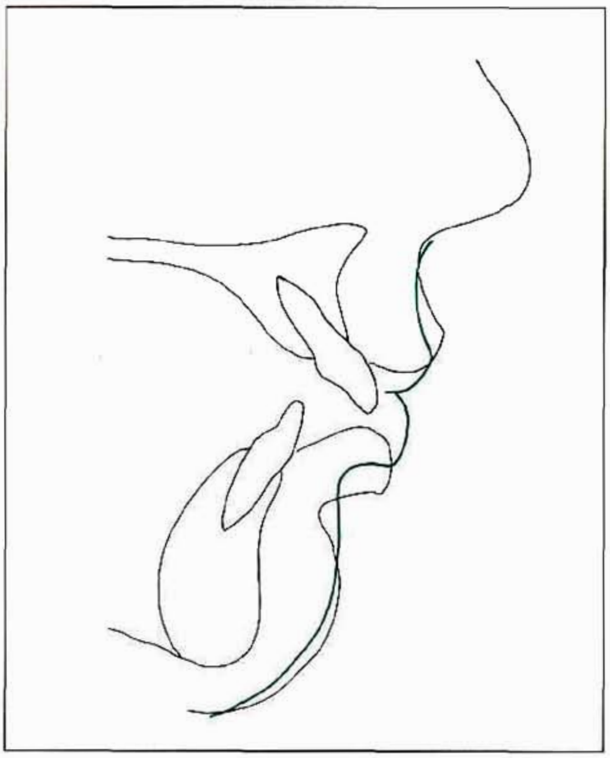


Fig 5-28 Patient who has a large interlabial gap with his lips at rest. For many such patients lip closure is difficult, and their habitual lip posture is lips apart. In addition, they may be mouth breathers. Reduction of these interlabial gaps can be accomplished by reducing the vertical dimension of the lower facial height or by retracting the incisors.

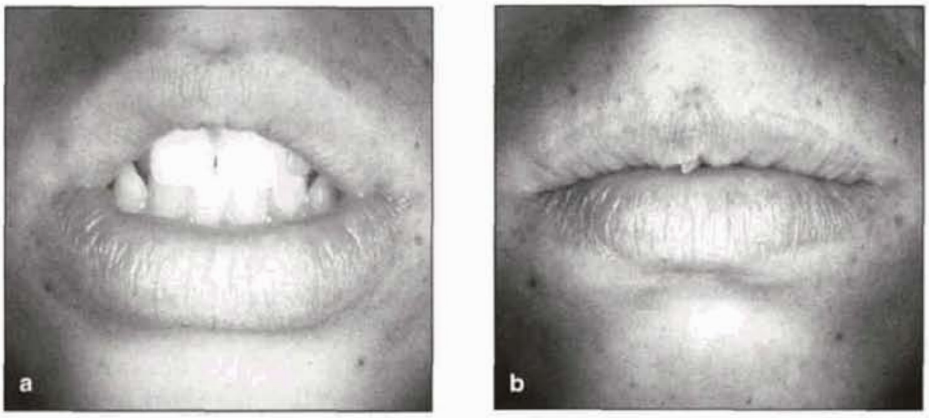


Fig 5-29 Contraction of the orbicularis oris and mentalis muscles presents problems of esthetics and stability during lip closure. Often, a habitual lips-apart position fails to provide adequate labial restraint to the incisors. a, Large interlabial gap in the lips-apart position. b, Large interlabial gap in the lips-lightly-touching position.

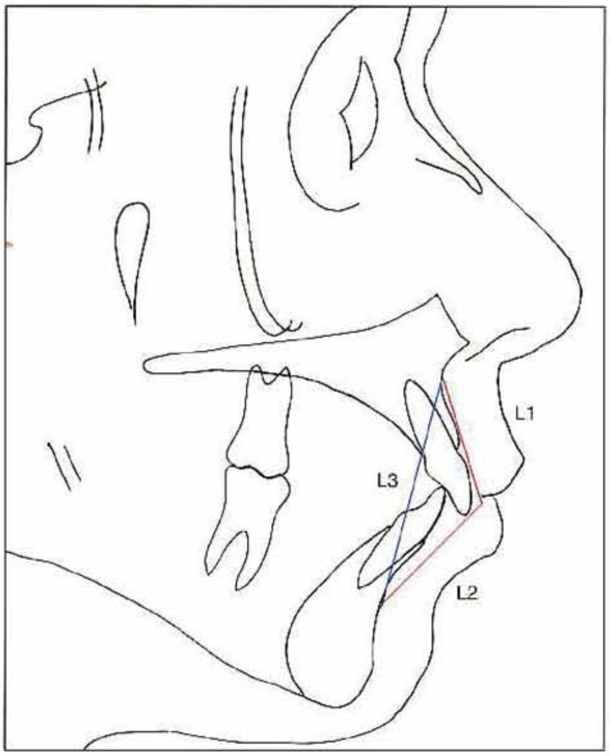


Fig 5-30 Shortening the distance over which the lips must close reduces the interlabial gap and facilitates lip closure. L3 is the shortest distance for lip closure.

In patients with excessively large vertical dimensions, it may be so difficult for them to close their lips that, even with the incisors retracted, their habitual lip posture may still be lips apart. How much retraction is required to facilitate closure of an excessive interlabial gap? In Fig 5-30, the point A–point B line (L3) represents the shortest distance over which the lips must close. In theory, then, the point A–point B line would be the limit for incisor retraction. While point A and point B can be modified somewhat, the point A–point B line would still represent the shortest distance over which the lips must close. Retraction of the incisors to reduce the interlabial gap and to facilitate lip closure can sometimes run counter to the production of good facial esthetics since the resulting lip retraction can be excessive; hence, when determining the desired incisor position, other factors must be considered.

An excessive interlabial gap can be caused by a large facial vertical dimension or short lips. One cannot assume, however, that all patients who have a long face always have a large interlabial gap. The lateral headfilms in Fig 5-31 show two similar dentoskeletal patterns. Figure 5-31a shows a large interlabial gap, while Fig 5-31b shows normal lip closure in spite of a large skeletal vertical dimension and protruding incisors. Longer than average lip lengths are more than adequate to achieve lip seal with minimal muscle contraction.

In patients with lip length redundancies (lips longer than the vertical skeletal height), the lips usually will not retract following incisor retraction. Lateral headfilms made before and after treatment of a patient who has a lip length redundancy demonstrate that the upper incisor retraction did not retract the lips (Fig 5-32). Note the retrolabial space (the open area lingual to the inner surface of the lips). The patient's arch length inadequacy was treated by means of tooth extraction; however, the same facial result could have been achieved without removing any teeth (that is, by flaring the lower incisors and maintaining the upper incisor position).

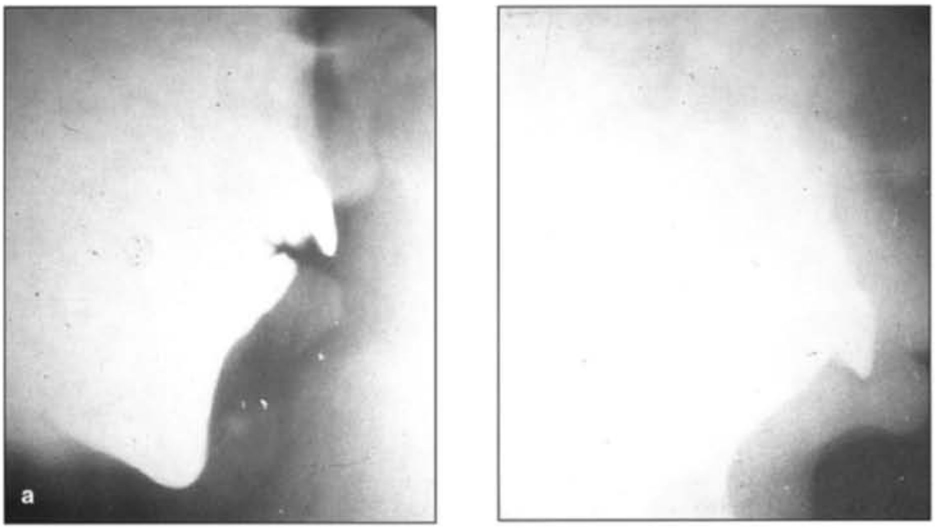


Fig 5-31 Two patients with similar dentoskeletal patterns. a, Large interlabial gap. b, No interlabial gap. Lip length is adequate for normal lip closure with minimal muscular contraction.

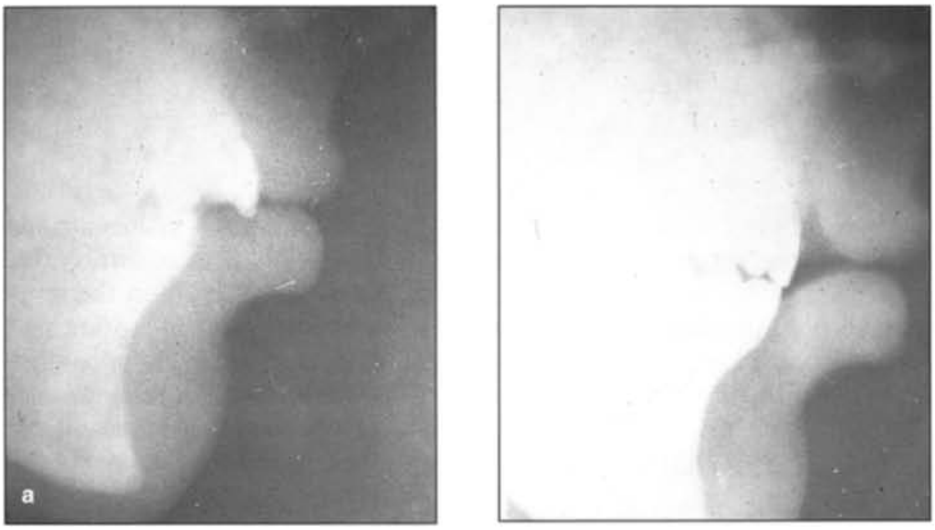


Fig 5-32 Patient treated by extraction of the premolars for upper incisor retraction. The lips did not retract because of the lip length redundancy. The space lingual to the lips (the retrolabial space) could have been used to flare the lower incisors, precluding the need for extractions. a, Before treatment. b, After treatment.

Patients with lip length redundancies often present the problem of overly protrusive lips. Sometimes it is thought that such patients have a small facial vertical dimension that needs to be increased through treatment. However, two entirely different muscle systems must be considered: the muscles of mastication and those of facial expression. The muscles of mastication are responsible for maintaining mandibular posture; most of these patients have a normal freeway space, and any attempt to increase the vertical dimension can result in instability. The problem is

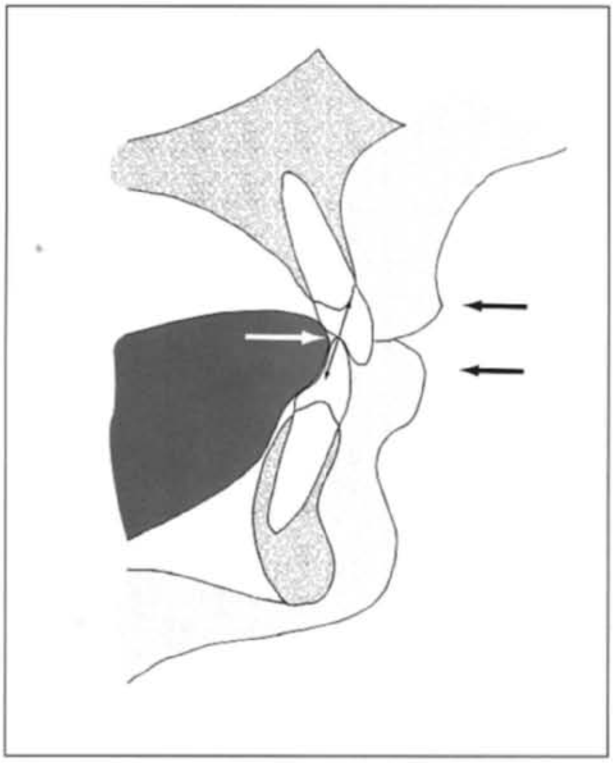


Fig 5-33 The stability of the incisors is determined by a combination of forces: tongue, occlusion, and lips. At any given moment, all forces are probably not in equilibrium. Unlike the cheek, the division of the lips into upper and lower components offers more possibilities for multiple positions of stability.

a lip length that is relatively long for the vertical dimension, and this is the result of two muscle systems that have matured independently of each other. Since their lips protrude away from the incisors, patients with a lip length redundancy can sometimes afford to have their incisors flared.

Anteroposterior Position of the Incisors and Its Effect on Stability

The dynamics of the anteroposterior stability of the incisor segments are slightly more complex than those that determine posterior arch widths (Fig 5-33). One factor that must be considered when determining posterior arch widths is the continuity of the cheek. Anteriorly, the orbicularis oris complex has dual components in the upper and lower lips, and these can operate either together or separately. For example, in some Class II, division 1 malocclusions, the lower lip can place lingual pressure on the lower incisor and labial pressure on the upper incisors; in these patients, the upper lip may have no restraining effect on the upper incisors.

In other Class II, division 1 malocclusions, the pattern of lip forces can be different because of the dual muscular components of the lips. Varying lip postures and pressures are present during any given 24-hour period. A patient with a very large interlabial gap can have a habitual lip posture of lips together during the waking hours; during sleep, the same patient's habitual lip posture could be lips apart. Normal oral slit length extends from canine to canine. In patients with an oral slit length extending from first premolar to first premolar, the dual lip components (the orbicularis oris complex) will be operating. In patients with short oral slits that extend mesial to the canines, the canines behave like cheek teeth. The complex facial musculature forming the orbicularis oris complex allows for varying lip postures in a patient. If the incisors are flared, mentalis muscle

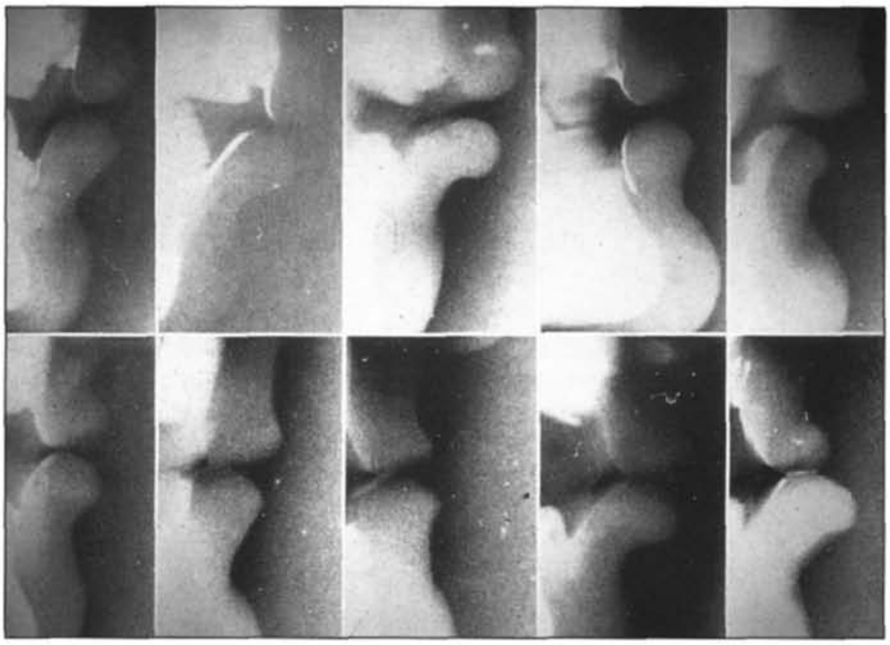


Fig 5-34 Lateral headfilms of edentulous young adults with lips at rest demonstrate horizontal and vertical lip posture. Lips at rest exhibit a horizontal posture and do not necessarily fall lingually when tooth support is lacking.(Courtesy of R. Robinson.)

contraction can displace the lower lip anteriorly to the incisors. In addition, dynamic occlusal and tongue forces act on the anterior segment of teeth (Fig 5-33).

Fortunately, in most patients the tongue can adapt to a new incisor position, though only to a limited degree. The presence of dual lip components, combined with a somewhat adaptable tongue posture, suggests that multiple positions of stability in the incisor region are possible. There may be more room to flare incisors than to expand canines. Muscle patterns are more easily modified in the lips than in the cheek.

In the Class II, division 1 malocclusion, for example, the lower lip may be lingual to the upper incisor before treatment; after treatment, the lower lip will function labial to the upper incisors.

In another patient, a large interlabial gap may be reduced by decreasing the vertical dimension and retracting the incisors. The habitual lip posture can be changed from open to closed by involving different muscle groups in lip closure.

This brief discussion of tongue posture, size, and function is not intended to minimize the importance of tongue factors; on the contrary, the tongue is key to understanding and treating open bites and bimaxillary protrusions.

Evaluation of Lip Posture

Earlier it was noted that the relaxed position is the best starting position for evaluating lip posture. When the lips are relaxed, the space between the upper and lower lips—the interlabial gap—can be measured. The space may be normal (about 2 mm), excessive, or nonexistent. In addition to this vertical assessment, the horizontal posture of the lips should be considered. In a study by R. Robinson, several young edentulous patients were fitted with bite blocks to establish vertical dimension, and then lateral headfilms were taken with the lips relaxed (Fig 5-34). These patients showed varying horizontal lip postures—forward or back—and in some cases vary-

Fig 5-35 Horizontal lip posture is observed with the lips relaxed. In this position, the lower lip usually contacts the middle of the lower incisor crowns.

Fig 5-36 A patient with a protrusive lip posture in the relaxed lip position. If the interlabial gap is not excessive, the incisors may be flared.

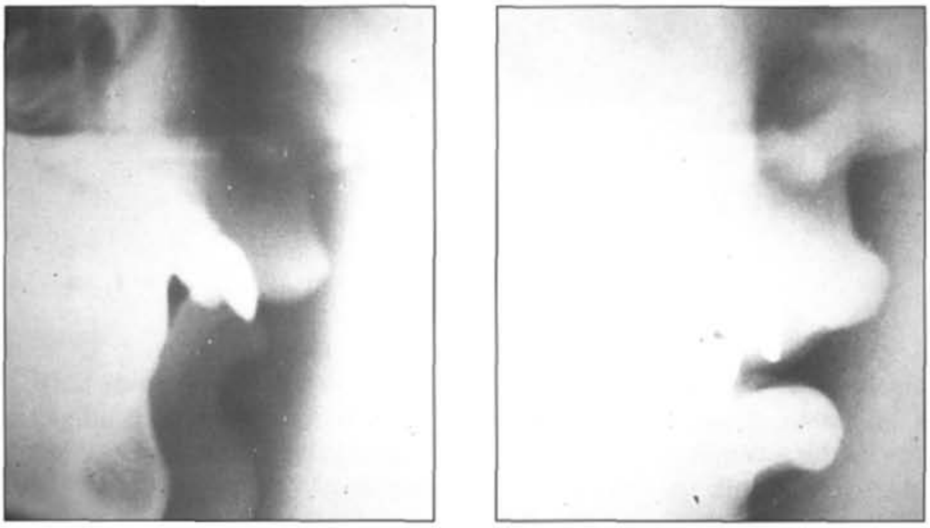


Fig 5-37 The facial esthetics of the patient on the left would be greatly improved by flaring the lower incisors and increasing the lower lip protrusion. The tense lower lip and its associated lingual lip posture suggests that this approach would be unstable. The patient on the right, who has protrusive lips and available retrolabial space, appears to meet the conditions that would render flaring of his incisors stable; however, the large interlabial gap is a contraindication.

ing vertical lip postures. Some patients with an interlabial gap even had excessively protrusive lips in spite of a total lack of tooth support. This suggests that a horizontal rest posture exists and that problems of stability can result if the teeth are moved labially into the lips.

When the lips are relaxed, the lingual surface of the lower lip usually contacts the middle of the lower incisor crown (Fig 5-35). Some patients have both a forward and a protrusive lip posture, as in Fig 5-36. Figure 5-37 shows the headfilms of two patients in their relaxed lip posture. The patient on the left has a tight, lingually postured lower lip. Esthetically it would be desirable to flare the lower incisors; however, they would then be pressed into the lip, resulting in questionable stability. By contrast, the patient on the right has a protrusive lip posture. Does this mean that the incisor can be flared? Not necessarily, since the interlabial gap is large and the lips will be postured further posteriorly during closure. The postural analysis of the lips should include an exami-

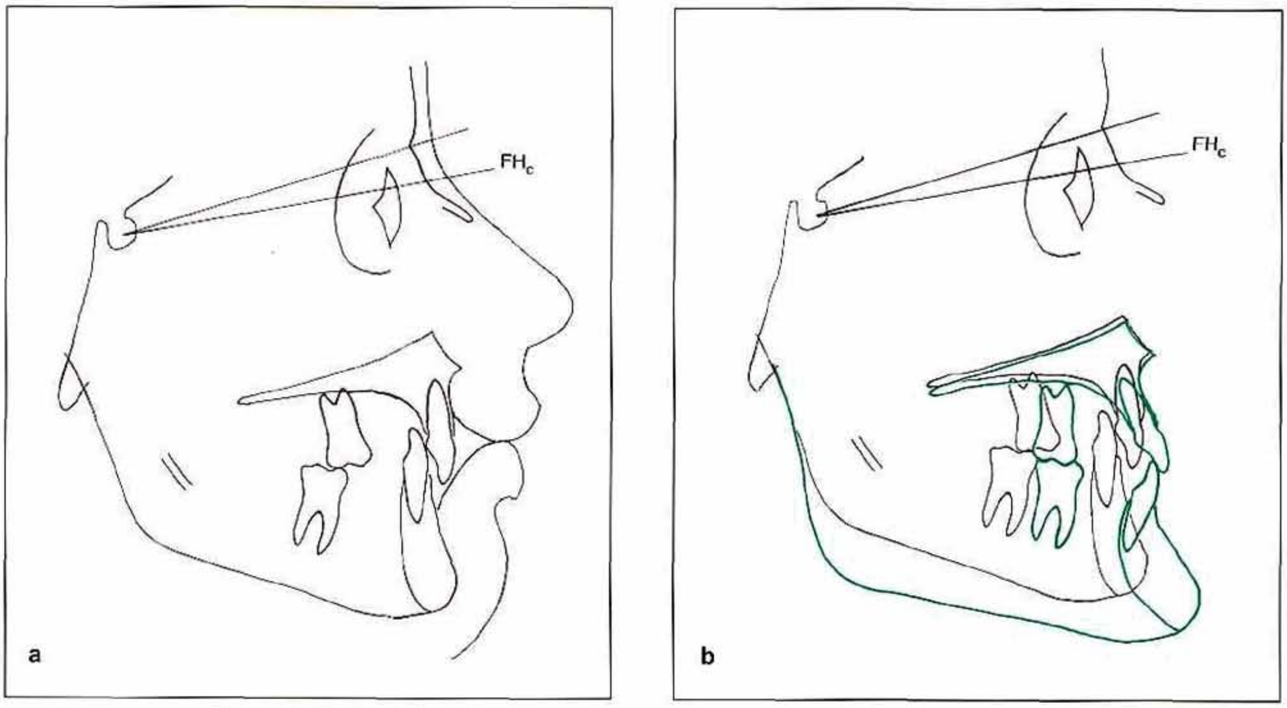


Fig 5-38 Patient BC presented with a Class II, division 2 malocclusion with a lip length redundancy. The redundancy and favorable mandibular growth allowed for successful treatment without the removal of any teeth. a, The large retrolabial space was used to flare both the upper and lower incisors. b, Differential maxillomandibular growth accounted for the Class II correction.

— original position — treatment outcome

nation of their vertical and horizontal position with the lips relaxed, followed by an analysis of the muscle activity and posture required to effect lip closure.

The male patient shown in Fig 5-38a, who was 14 years of age at the start of treatment, had a lip length redundancy; moreover, his lips projected away from his incisors. The retrolabial space of the upper and lower incisors before they contact the lingual surface of the lips allowed room for flaring, simplifying the treatment of this Class II, division 2 malocclusion. Headgear was used in the maxillary arch, and subsequent differential mandibular growth accounted for the dramatic correction that took place (Fig 5-38b). The amount of mandibular growth that took place during the approximately 3-year interval separating the initial and final headfilms is more than would be expected in a male of this age, but it is not unusual.

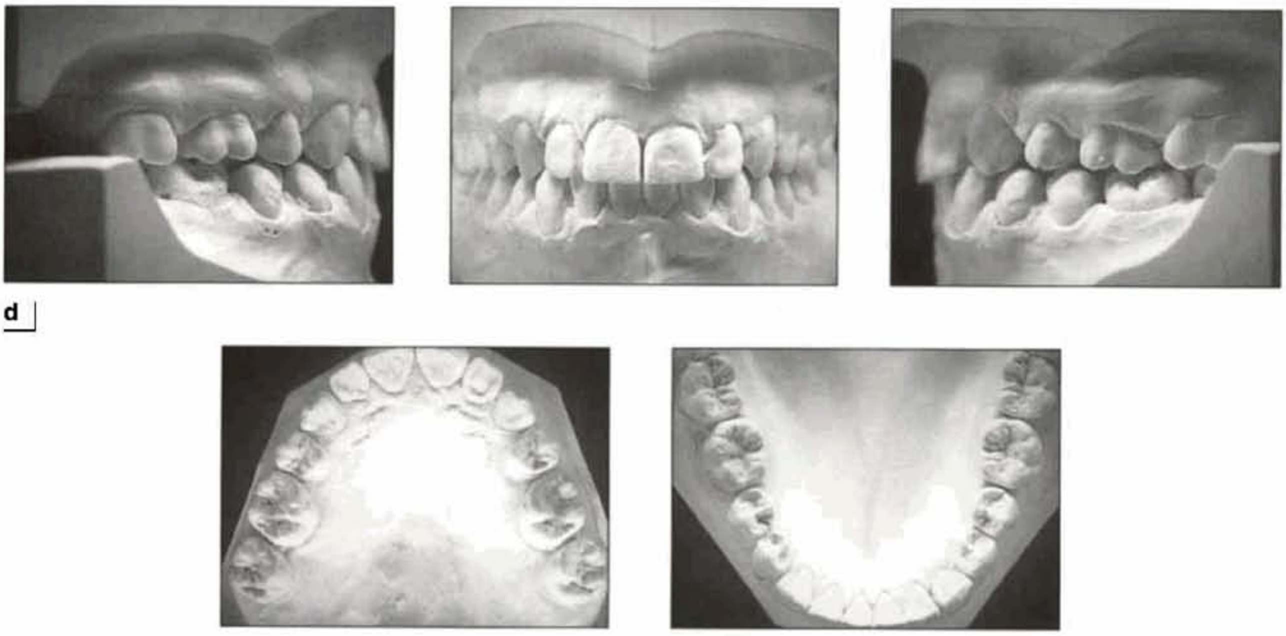
Many patients with a Class II, division 2 malocclusion have a smaller than average vertical dimension and may exhibit a lip length redundancy, allowing for flaring of the incisors and precluding the removal of any teeth. Patient DP, who presented with a Class II, division 2 malocclusion (Fig 5-39), is very different. The lower lip is pressed tightly against the upper incisor, and no vestibular space is available in which to flare the upper incisors. Because growth had already been completed in this patient, differential jaw growth was not an option for correcting the Class II malocclusion. The upper first premolars were removed and the crowns of the upper incisors underwent lingual root movement (Fig 5-39e). As a result, the lip relationship to Sn–Pg' improved (from +1 mm/–2 mm to +3 mm/+0.5 mm); however, the flaring of the lower incisors may not be stable.

Fig 5-39 Patient DP presented with a Class II, division 2 malocclusion and a tense lower lip. Although flaring the incisors would have been esthetically more pleasing, stability would have been in doubt. The upper first premolars were removed to maintain the anteroposterior position of the upper incisors. a, Profile before treatment. b, Profile after treatment. c, Study casts before treatment. d, Study casts after treatment. e, Initial cephalometric tracing. Note how the upper incisor is pressed into the upper lip. f, Cephalometric superpositions. g, Subnasale–soft tissue pogonion superposition. Lips are more protrusive after treatment. h, Upper occlusogram treatment-plan tracing. i, Lower occlusogram treatment-plan tracing. Molars are maintained in the original position and the incisors are flared.

a

b

c



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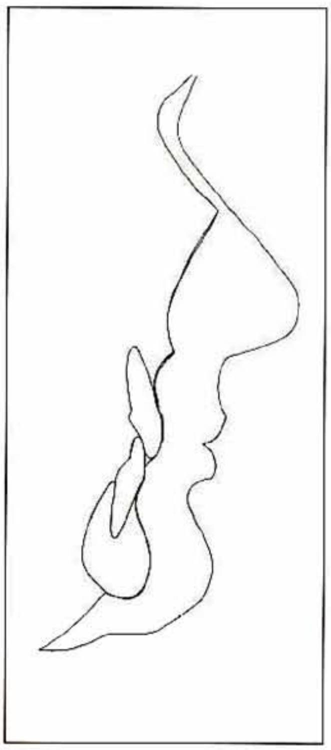

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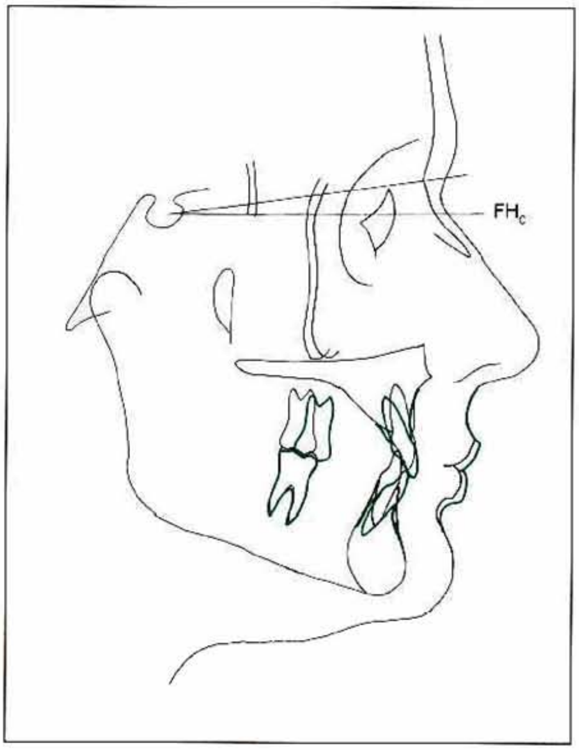

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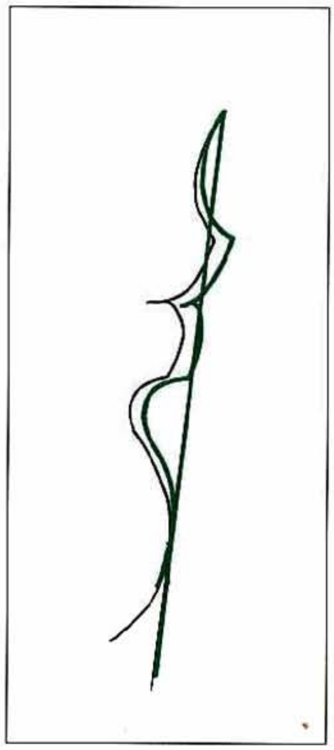
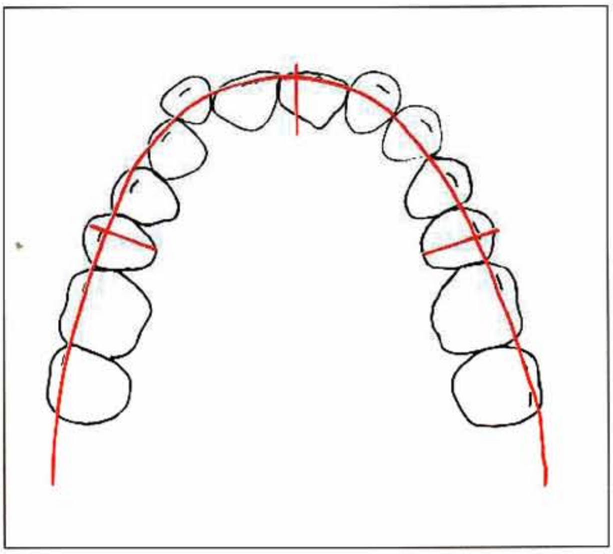


g

— original position — treatment outcome



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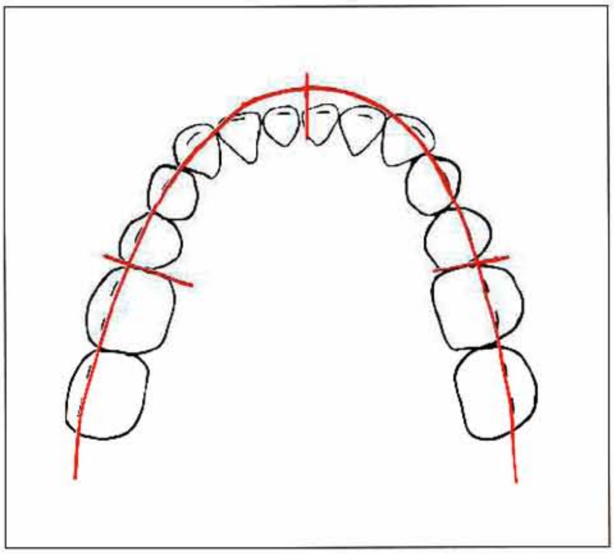

i

Patient LR presented with severe occlusal problems, missing lower first molars, and impacted upper canines (Fig 5-40). Although the lower lip pressed firmly against the incisors, the lower lip protrusion relative to Sn–Pg' was normal before treatment. The question was whether to retract the upper incisors, which would produce undesirable concavity in the lip area, or to flare the lower incisors for a more esthetic but potentially unstable result. The decision was made to retract the upper incisors and to close spaces in the lower arch by bringing the second molars forward while maintaining the position of the lower incisors. Treatment goals were achieved with only slight retraction of the lower incisors. The upper incisors were translated lingually and retruded to produce a more esthetic smile line. The impacted upper canines were removed to accommodate the anterior retraction. The result of treatment is an esthetically compromised face: the lower lip is posterior to the Sn–Pg' line, the angle from the chin to lower lip to upper lip is concave, and this lip concavity is exacerbated by the increased nasolabial angle. The step between the upper and lower lips is caused by greater lower lip retraction than upper lip retraction, which is not unusual. It is possible that a reduction genioplasty could improve the facial esthetics; as soft tissue pogonion is retracted, the lips would become more protrusive to the Sn–Pg' line. An alternate strategy of flaring the lower incisors and placing bridges or implants in both arches would have produced a more esthetically pleasing result; however, it also carries disadvantages of permanent retention and long-term prosthetic management.

Fig 5-40 Patient LR presented with missing lower first molars and impacted upper canines. Spaces were closed to avoid the need for fixed partial dentures or implants; some flattening of the lip profile was anticipated. a, Facial photographs before treatment. b, Facial photographs after treatment. c, Study casts before treatment. d, Study casts after treatment. e, Cephalometric superpositions. f, Soft tissue superpositions showing lip retraction and an increase in the nasolabial angle. g, Upper lip–lower lip–chin angle is concave at the end of treatment; normally, this angle is 0 degrees, or a straight line.

a

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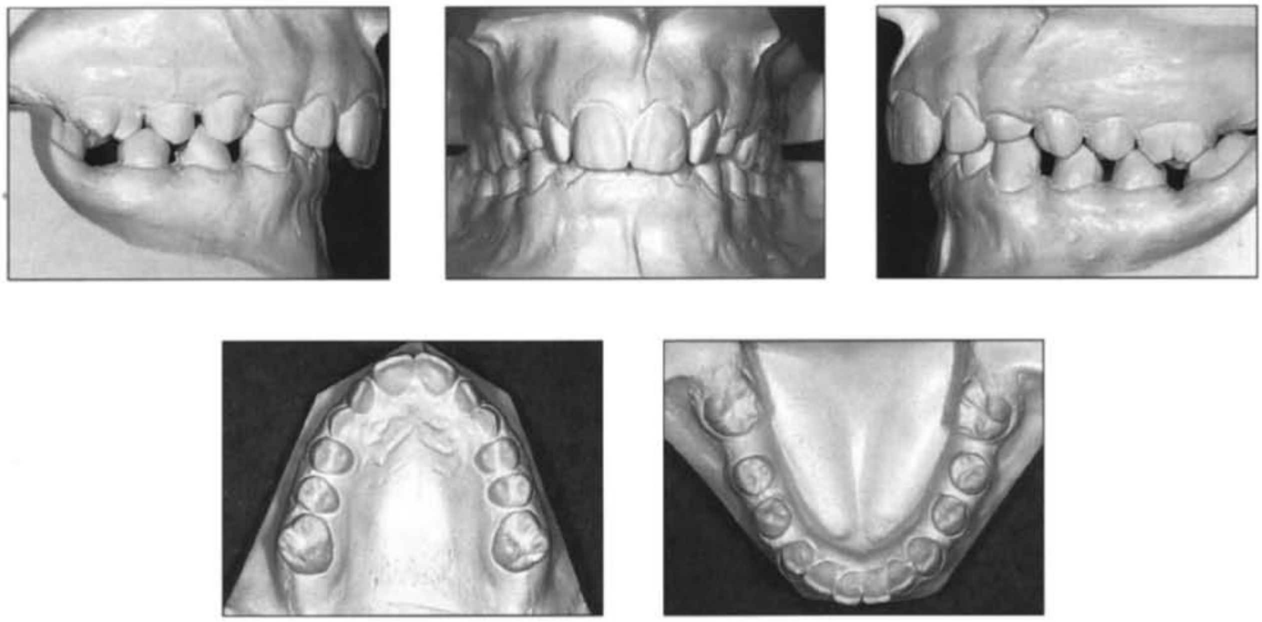

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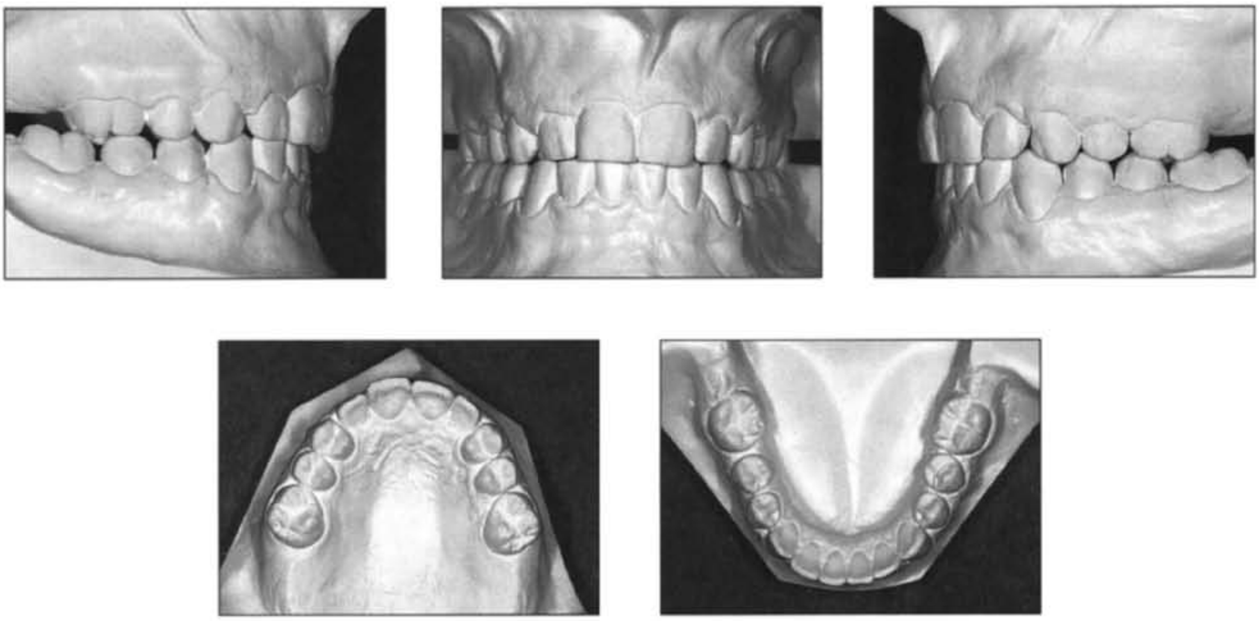

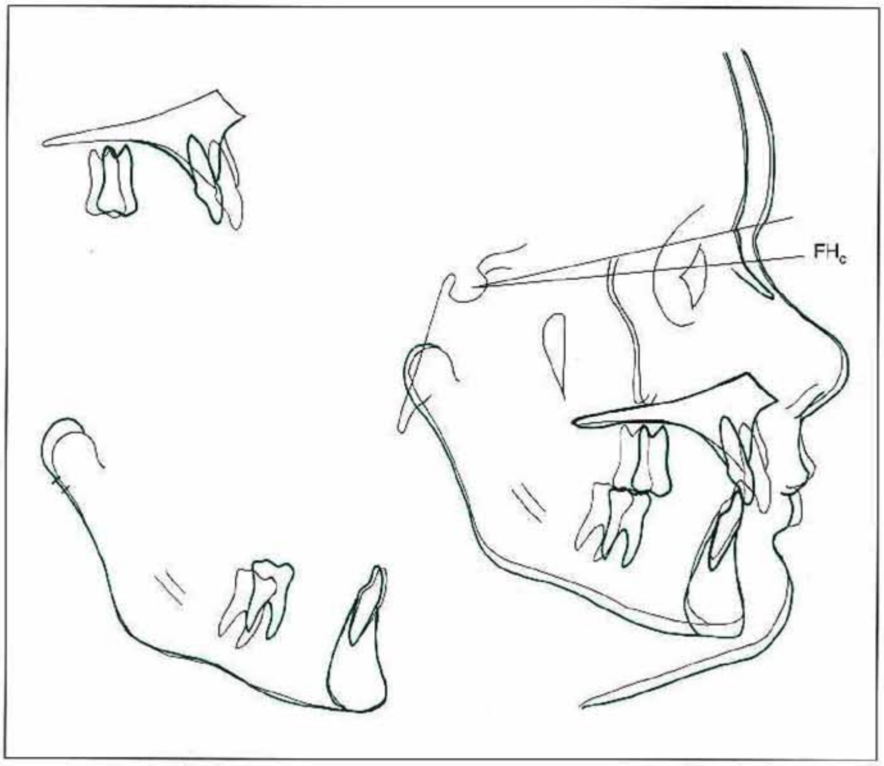

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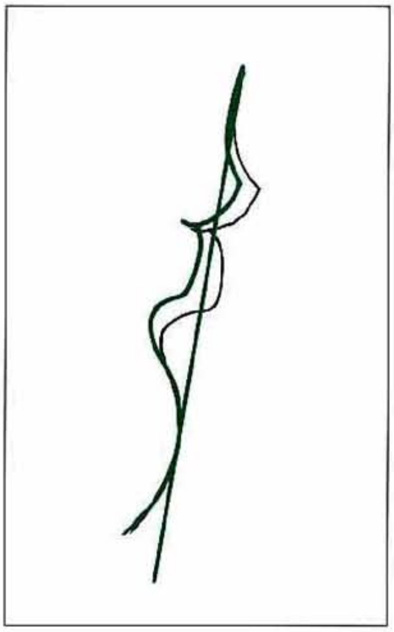

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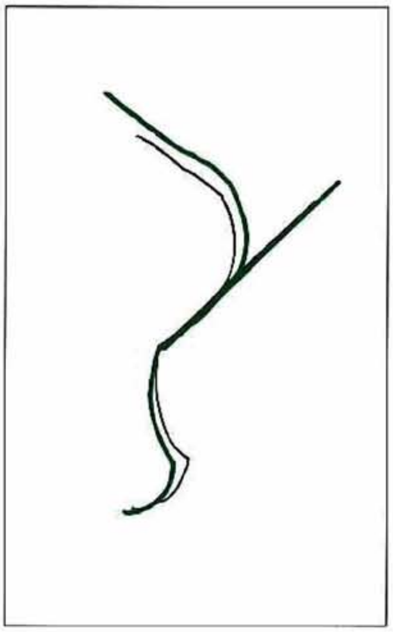

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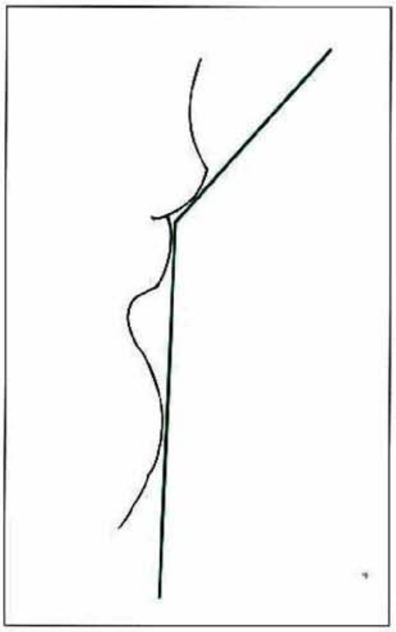


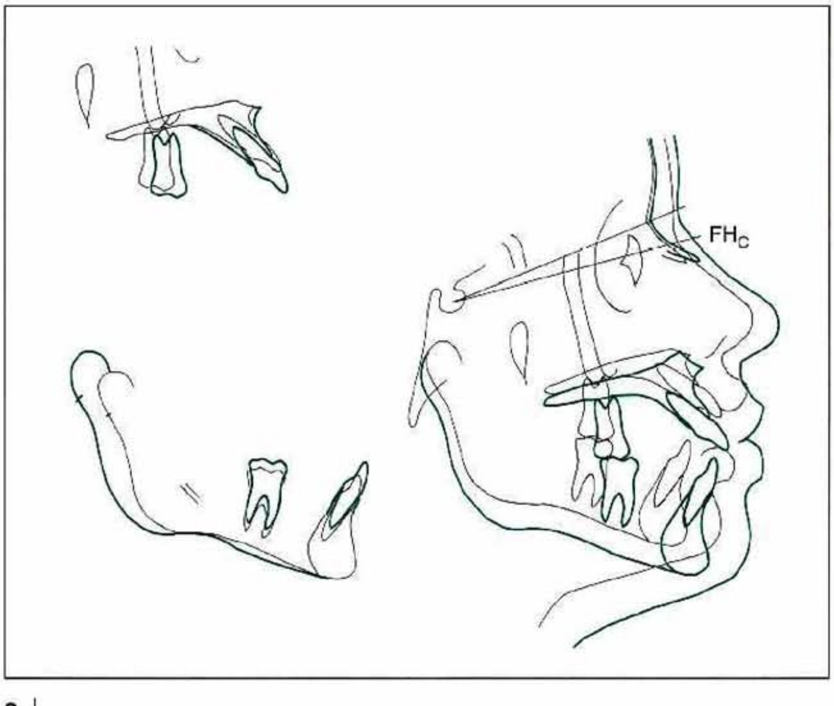
g

— original position — treatment outcome

Fig 5-41 Patient AM, a 9-year, 9-month-old female, presented with flared incisors associated with a forward tongue posture. a, Frontal dental photographs before treatment. b, Dental photograph after the first phase of treatment, during which the upper incisors were retracted and extruded. Seven years later, without further treatment or retention, the incisors had flared forward to where they would most likely have been without orthodontic intervention. c, Cephalometric superpositions of initial lateral headfilm (black) and a headfilm taken 7 years later (green).

a

b



c

Much emphasis has been placed on the importance of lip factors in determining the ideal position of the incisors. However, careful consideration should also be given to tongue morphology and function. Patient AM has a forward tongue posture at rest and an anteriorly protruding tongue during swallowing. She received first-phase treatment during her mixed dentition stage: the upper incisors were extruded and retracted (Figs 5-41a and 5-41b). Seven years later a complete relapse was evident. Superposed lateral cephalometric tracings show that the incisors flared to the position where they would have been had no first-phase treatment been instituted (Fig 5-41c). Although the tongue is usually adaptable, it cannot be encroached upon in some patients, for various reasons.

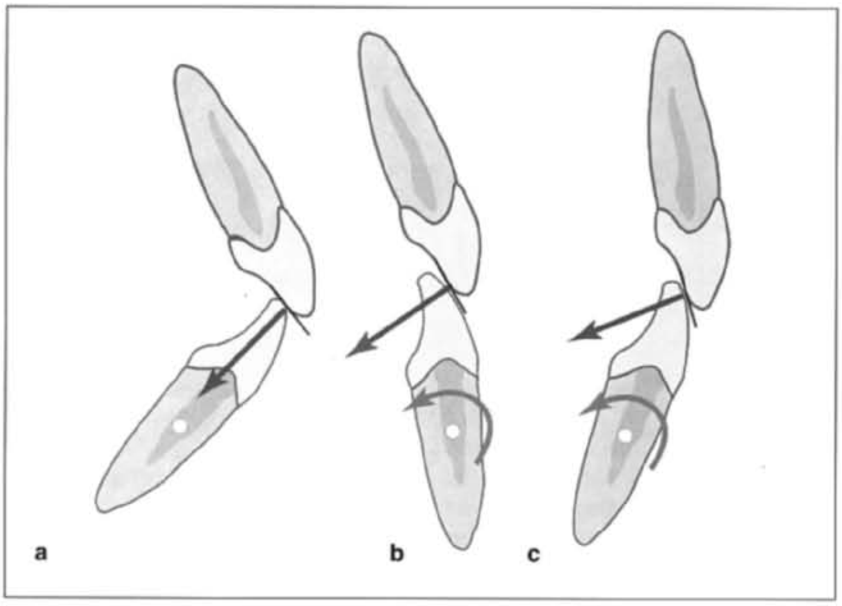


Fig 5-42 Occlusal forces affect the stability of the lower incisors. a, Force directed along the long axis of the lower incisor. b, Class III skeletal pattern compensations. The lingual force is superior to the center of resistance of the lower incisor, producing a moment tending to tip the lower incisor to the lingual. c, Vertical upper incisor axial inclination in a poorly treated Class II malocclusion results in a moment tending to tip the lower incisor to the lingual.

Like labiolingual forces, occlusal forces represent an important part of the stability equation. At the termination of the incisal cycle, force is applied to the lower incisors at 90 degrees to the functional lingual incline of the upper incisors. Depending on the axial inclination and position of the incisors, different effects are produced. Figure 5-42a shows the incisal force through the center of resistance at maximum occlusion (no moment is present and only an intrusive component acts on the lower incisor). In Fig 5-42b, the lower incisor has a lingual inclination, which is often seen in a Class III skeletal pattern. The lingual incisal force is now superior to the center of resistance, producing a moment tending to move the lower incisor lingually. Occlusal forces can be a factor in the development of compensations in a Class III malocclusion and in the stability of the occlusion after treatment. Figure 5-42c shows the axial inclination of the incisors in a poorly treated Class II malocclusion: the upper incisors are too vertical. The lingually directed biting force passes superior to the center of resistance, and hence could be a factor in the posttreatment crowding of the lower incisors. Some nonextraction treatments require flaring of the lower incisors. Since these axial inclinations are atypical, some orthodontists believe that it is better to normalize them by moving the roots labially. Such movement shifts the point of force application superior to the center of resistance and may lead to instability and future posttreatment crowding of the lower incisors. In this analysis, the moments on the upper incisors are less important since the lips continually restrain the upper incisors from moving labially. Functional movements are of course much more complex than this simple static analysis suggests, but there is no question that occlusal forces play a role in the stability of the lower anterior teeth.

It is a common clinical observation that patients treated for deep overbite tend to have less crowding of the lower incisors. There are two possible explanations for this: first, because of the overjet and overbite, the lower lip is further away from the lower incisors; and second, the occluding contact of the lower incisor is between the two lingual inclines of the upper incisor,

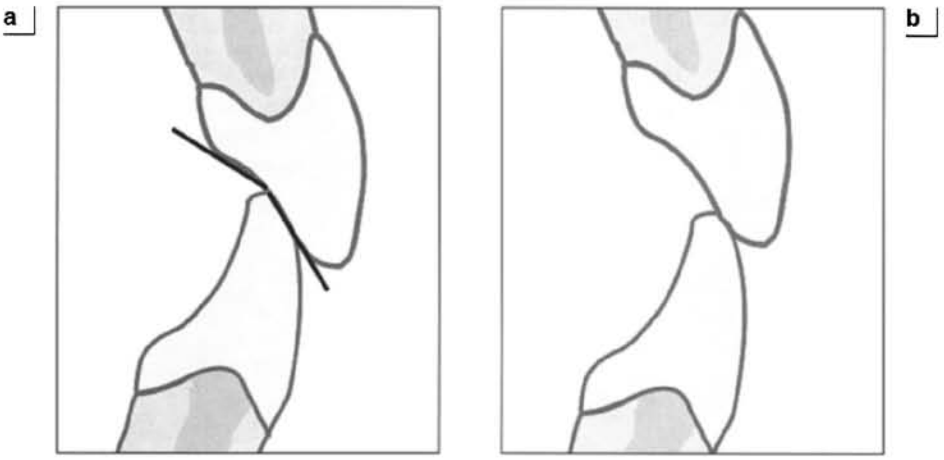


Fig 5-43 a, The lingual inclines of the upper incisor meet to form a wedge, the apex of which is called the registration point. Overbites of 30 to 40% can take advantage of this wedge by making the contact area more horizontally oriented, increasing the stability of the lower incisors. b, An orthodontic patient treated to 20% or less overbite has an occluding upper incline that is too vertically oriented; this can lead to moments tending to tip the lower incisor lingually.

which creates an orientation wedge (Fig 5-43a). The further apical the contact, the more horizontal is the contacting surface, which directs the force closer to the center of resistance of the lower incisors. This intersection or *registration point*, described by some gnathologists as the ideal point for lower incisor contact, creates 30 to 40% overbite. Currently, ideal orthodontic treatment produces an overbite of about 2 mm, or 20% (Fig 5-43b). It is possible that this concept of what constitutes a normal overbite is not the most stable position that can be achieved. More overjet and a slightly deeper overbite may be desirable at the end of treatment to minimize the problem of crowding in the lower anterior region. This might also explain the greater stability of the lower incisors in patients in whom one lower incisor is extracted, which leads to greater overjet and overbite.

Three factors have been considered in the anteroposterior positioning of the lower incisors: facial esthetics, lip protrusion, and perioral function as it relates to both ease of lip closure and stability. Only after considering each of these factors separately can the orthodontist determine the optimal position of the incisors. However, in the face of so many unknowns and conflicting objectives, a value judgment must still be made. There is no assurance that a stable position will be the most esthetic or that the reduction of the interlabial gap will produce good esthetics or enhance stability. In the past, treating by the numbers to a cephalometric standard made the orthodontist's work much simpler. Now one must look at many factors, not all of which are known or clear. Still, the dilemma of incisor stability should not prevent the orthodontist from making the best judgment as to what would be most stable.

Axial Inclination of the Incisors

For any given anteroposterior position of the incisors, a determination of labiolingual axial inclination must be made. In a patient requiring retraction of the lower incisors, the options are limited. The teeth may be tipped around their apices or further incisally around some point on the root (Fig 5-44a). It is not possible to position the root apex very far lingually since typically the roots are very close to the lingual plate of bone

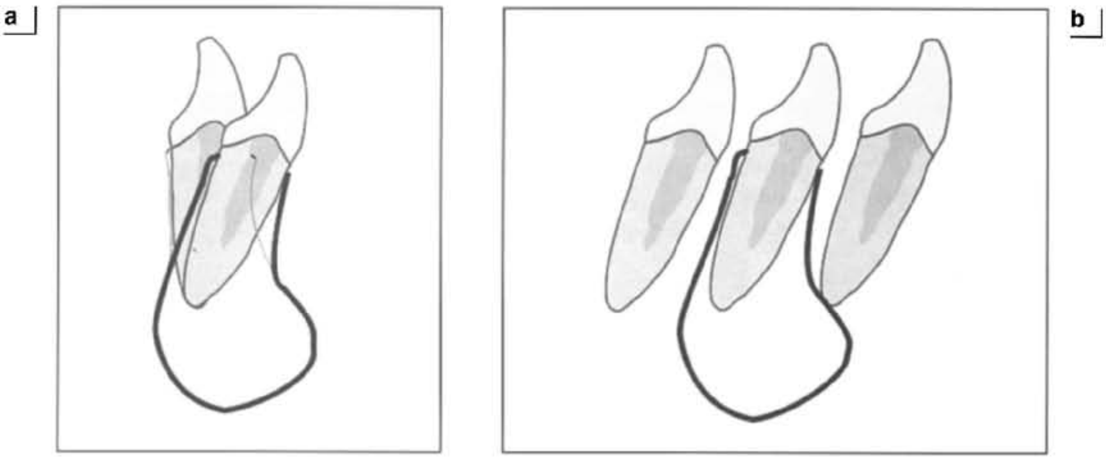


Fig 5-44 Movement of the lower incisor is limited by the amount of supporting basal bone in the mandible. a, Tipping movements maintaining the root apices are possible. b, Translation is limited if the roots of the lower incisors are to be maintained within the basal bone.

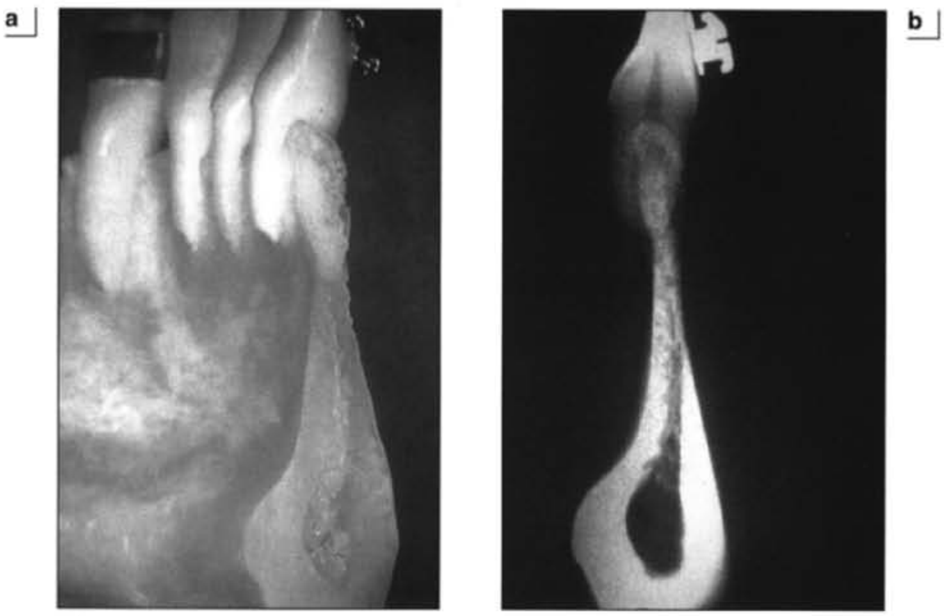


Fig 5-45 a, Autopsy specimen of roots that have been displaced through the lingual plate of bone during orthodontic treatment. b, Cross-sectional radiograph of 5-45a. (Courtesy Prof P. Dietrich, Klinik für Kieferorthopädie der TWTH, Aachen, Germany.)

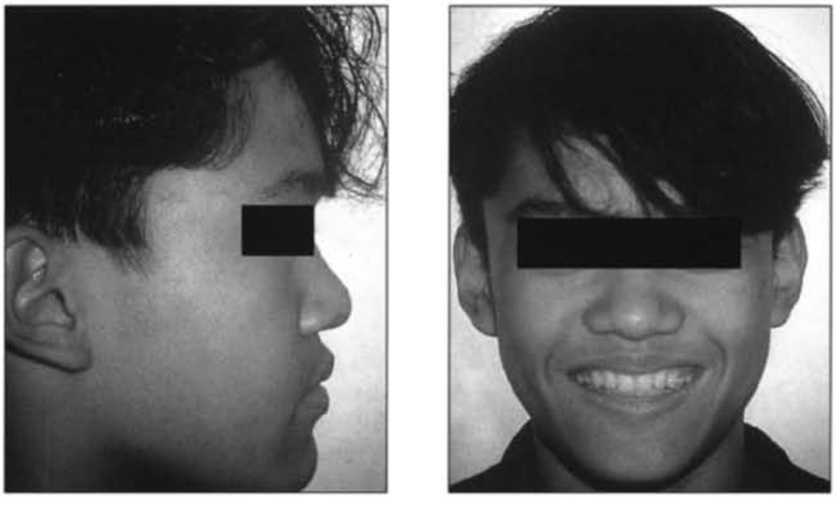
and thus can easily perforate it in a lingual direction (Fig 5-44b). Movement of the root apex labially without perforating the labial plate is also limited.

Figure 5-45a shows an autopsy specimen in which the lower incisor root apex is displaced through the lingual plate of bone. During a clinical examination, radiographs and palpation must be used to determine root apex position. A common error is to use "torqued" brackets to produce normal axial inclinations without concern for the supporting apical bone. In some instances this can lead to perforation of lingual or labial plates of bone. Note in Fig 5-45b that the axial inclination of the incisor is normal, but biologically incorrect.

Fig 5-46 Patient who presented with a bimaxillary dental protrusion with excessive lip protrusion. Lingual root movement of the upper incisors was possible because of sufficient palatal bone. In addition, the incisor intrusion moved the root into an area of sufficient bone, unlike the limitation of the lingual root movement of the lower incisors in the mandibular symphysis. a, Facial photographs before treatment. b, Facial photographs after treatment. c, Before treatment intraoral photographs. d, After treatment intraoral photographs. e, Cephalometric superpositions. f, Subnasale–soft tissue pogonion superposition. Significant incisor retraction resulted in marked lip retraction.

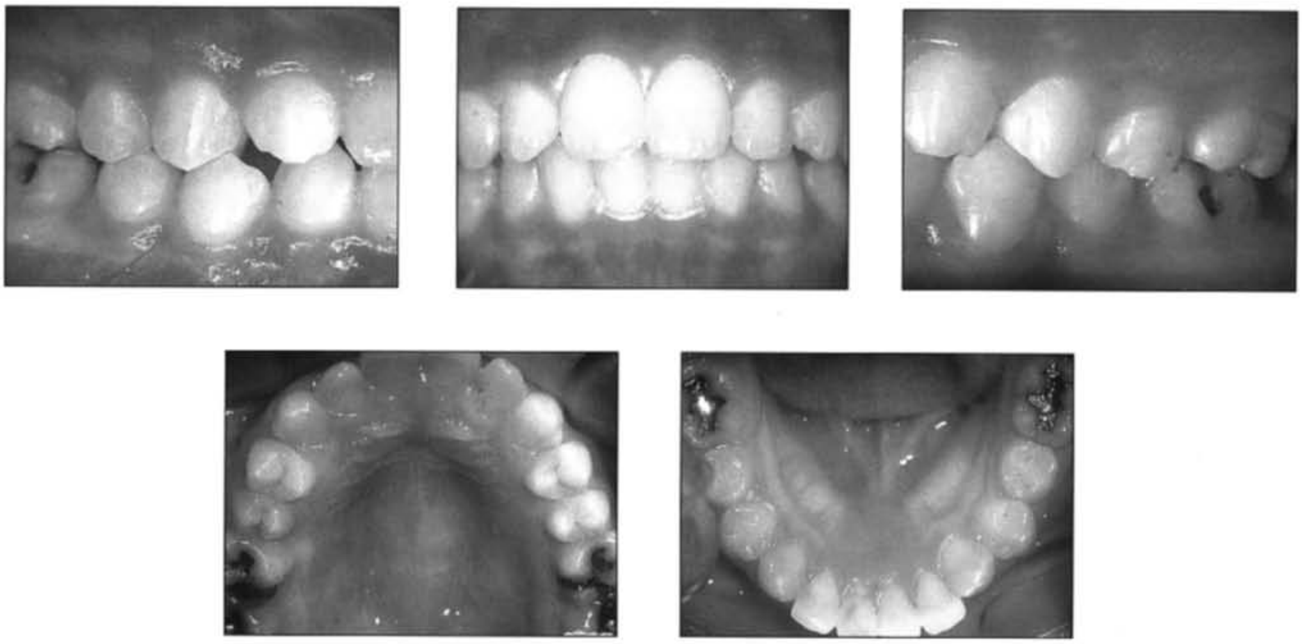
a

b



Fortunately, in the upper arch the palatal bone allows room for lingual displacement of the root apex. If treatment calls for incisor intrusion, more bone is available for root placement. The patient shown in Fig 5-46 presented with a relatively normal occlusion, a large interlabial gap, and protrusive lips. The primary concern of both the patient and his parents was his excessive lip protrusion. Four first premolars were extracted with the goal of maximum incisor retraction. The tracing of the lateral headfilm shows retraction of the lower incisors by tipping, with the apex as the center of

c



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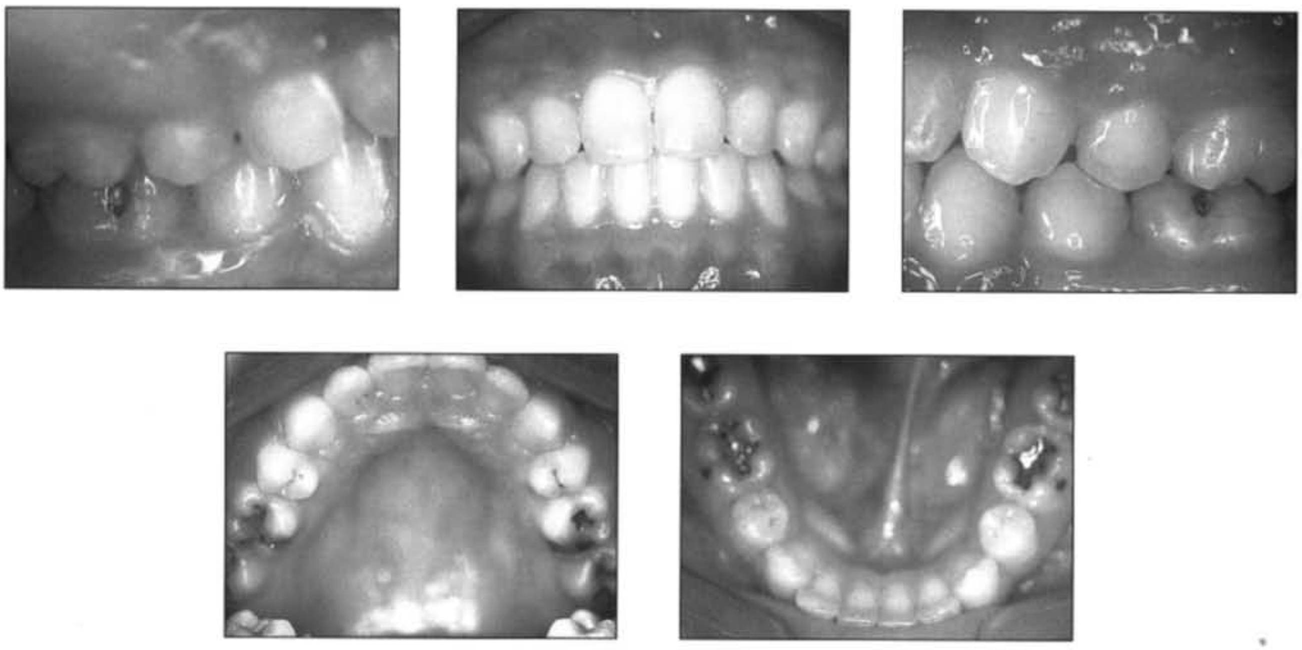

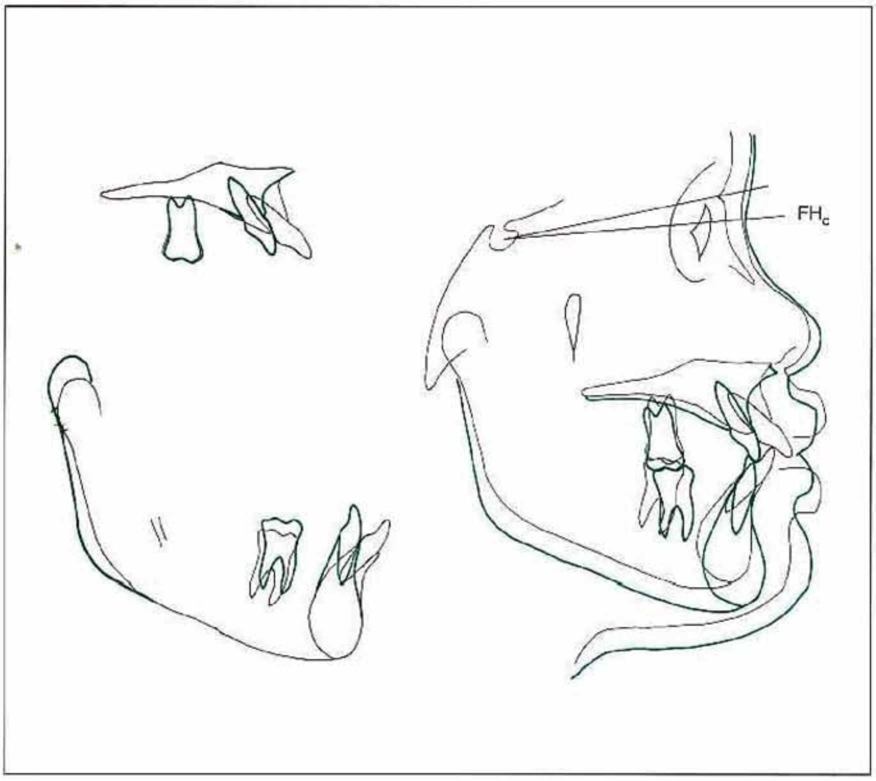

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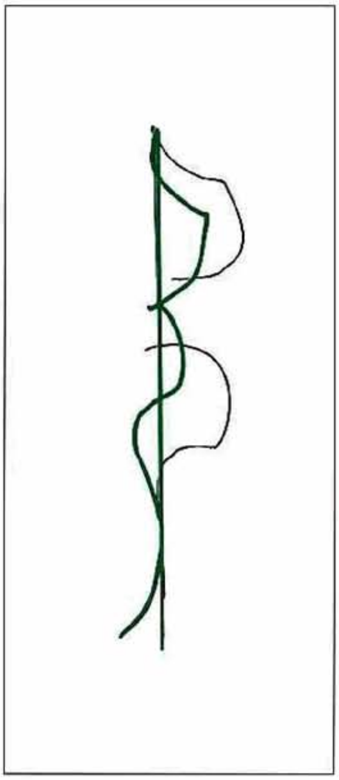


f

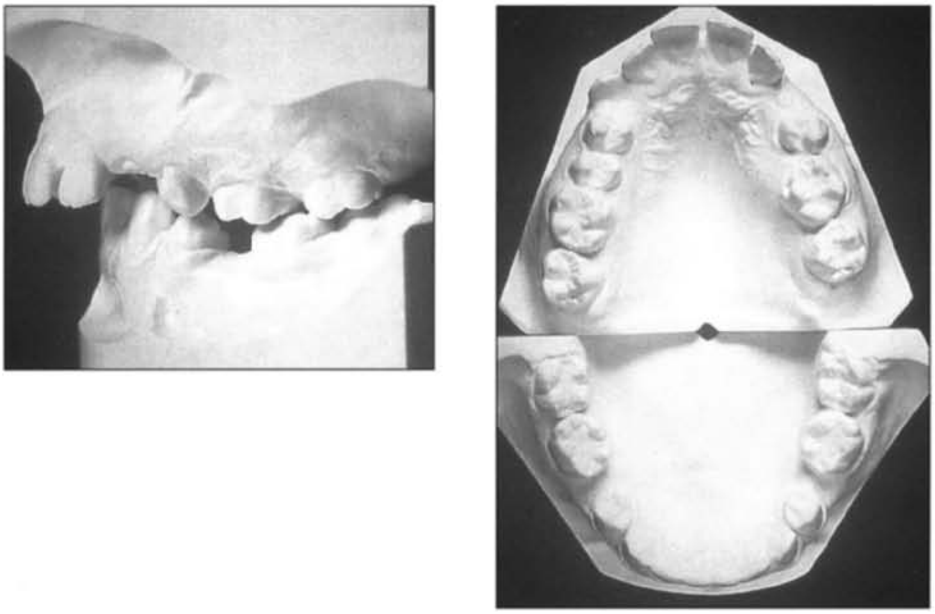
— original position — treatment outcome

rotation. The basal mandible did not change, but considerable remodeling occurred labially and lingually in the alveolar process. The roots of the upper incisors were moved lingually to give the incisors favorable axial inclinations. This was made possible by the abundant bone in the palate and by the incisor intrusion, which allows for potentially greater lingual movement of the apex. The improvement in facial profile is a result of both incisor retraction and mandibular growth.

The potential benefits of alveolar remodeling in the maxilla are shown in Fig 5-47. Patient VD presented with an asymmetrical posterior occlusion—that is, more Class II on the left. An arch length inadequacy in the mandible prevented eruption of the second premolars. Space was created in the mandibular arch by distal movement of the molars and some flaring of the incisors. Asymmetrical mechanics in the upper arch maintained the left molar position while advancing the right molar. The upper incisors were translated lingually. Note the remodeling of the alveolar process both at point A and at the lingual alveolar process. The upper incisor retraction improved perioral function, allowing a more esthetic and functional closure of the interlabial gap.

Fig 5-47 Patient VD presented with an asymmetrical buccal occlusion that was treated by the removal of upper premolars and asymmetrical mechanics in the maxilla. The upper incisors were translated lingually. a, Study casts before treatment. b, Study casts after treatment. c, Lateral treatment-plan tracing. Initial tracing (black), 2-year growth prediction (blue), and planned tooth position (red). d, Treatment-plan occlusogram showing asymmetrical right molar protraction in the maxilla. e, Before and after lateral headfilm tracings. The presence of bone in the palate allowed lingual translation of the upper incisors. f, Before and after occlusogram. Note asymmetrical space closure in the upper arch.

a



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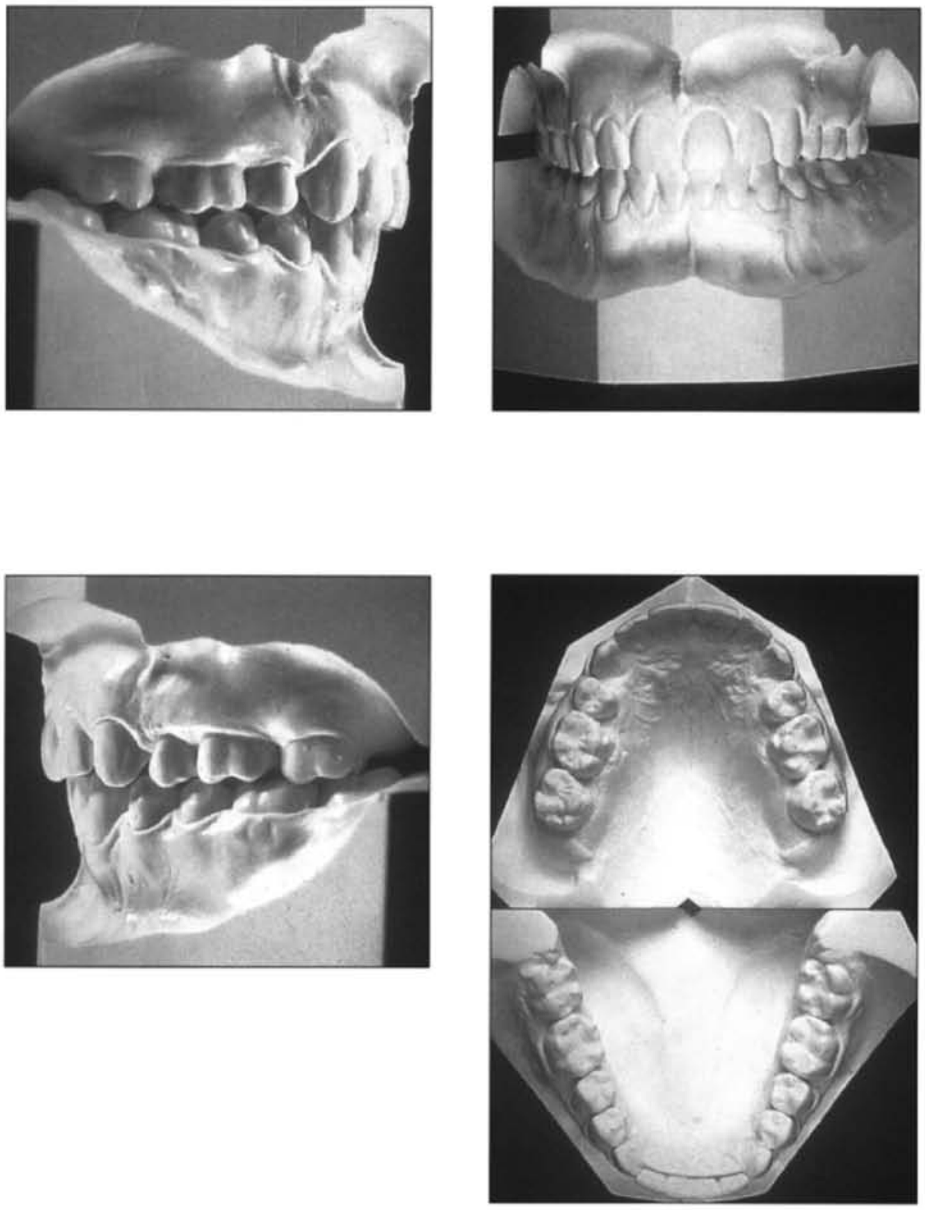

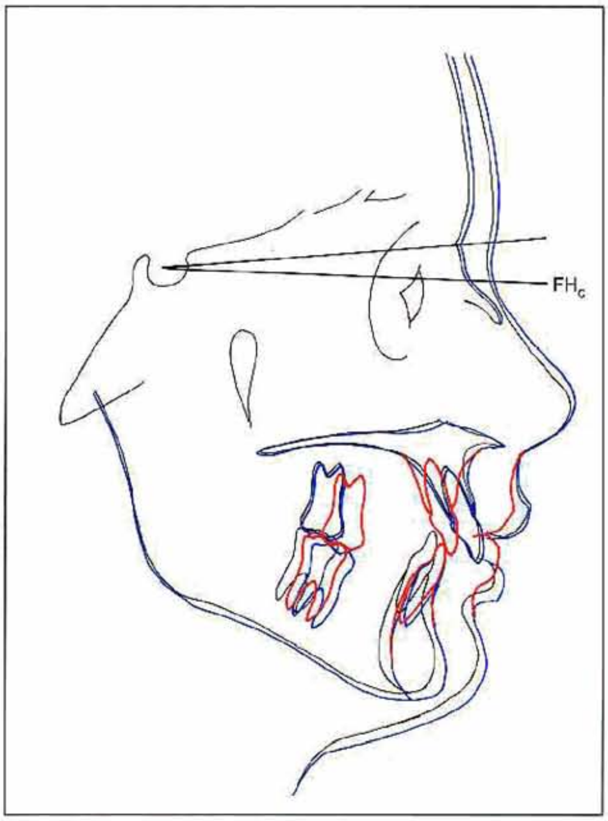

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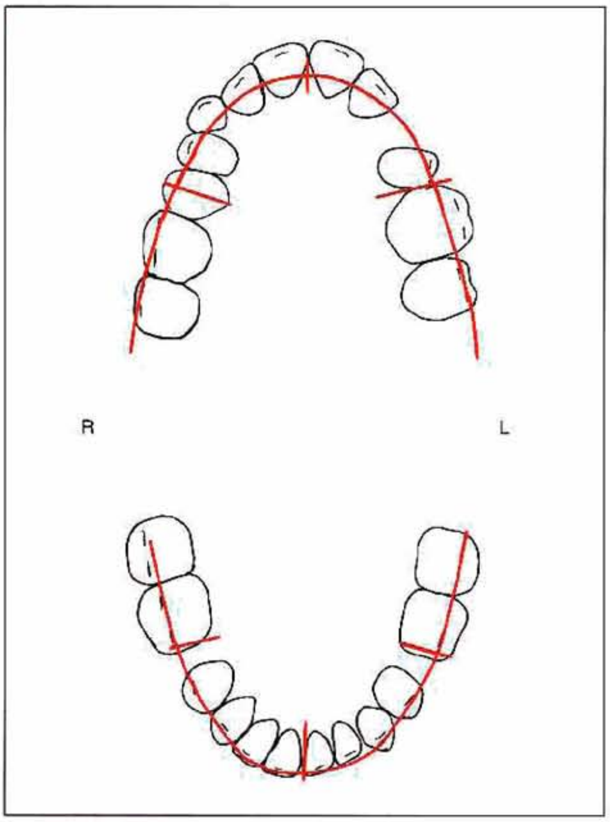

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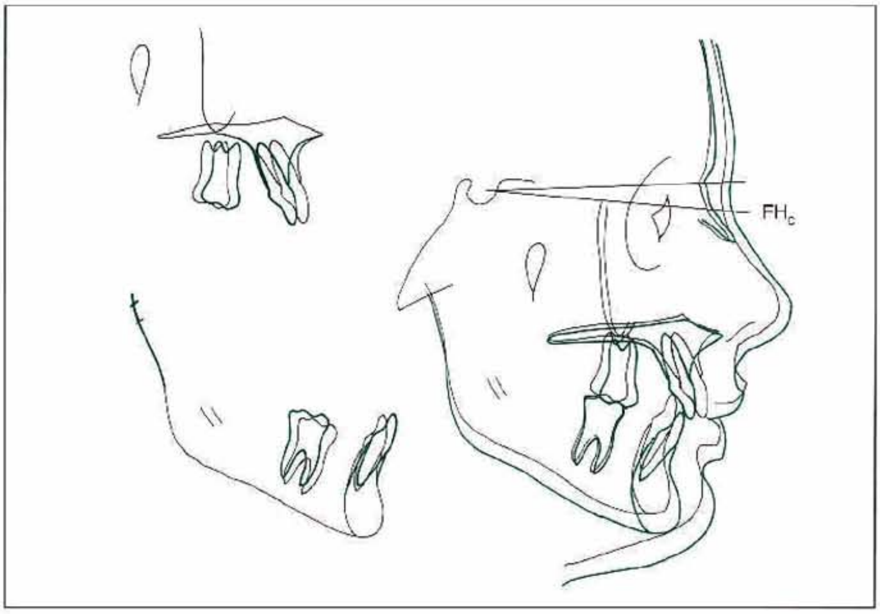
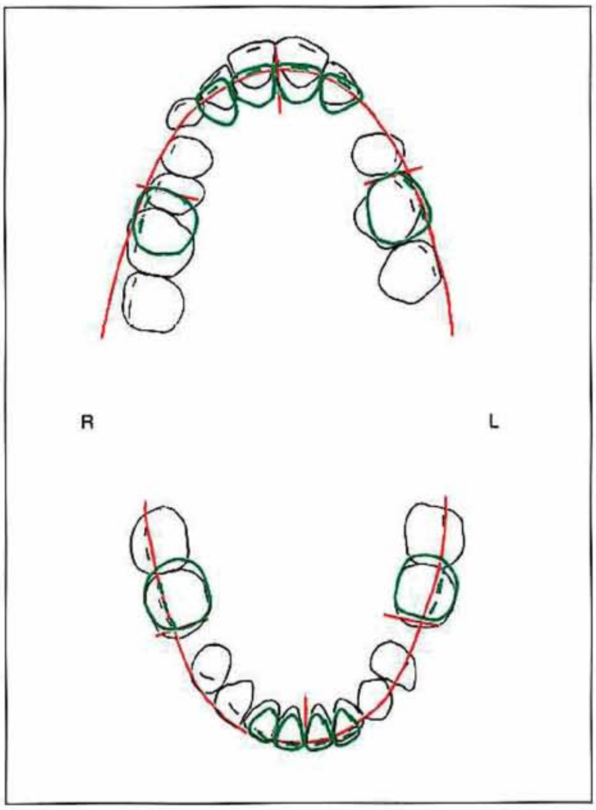
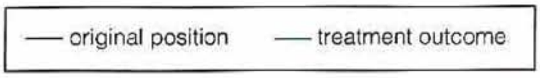


e

— original position — projected growth — treatment objective — treatment outcome





What is the ideal axial inclination for the upper incisors after treatment? As noted above, cephalometric standards should not to be used as treatment goals. When they look at their upper incisors in the mirror or in a photograph, our patients do not know that on average the angle of the upper incisor to Frankfort horizontal is 110 degrees. Does this mean they cannot recognize upper incisors in linguoversion if they are not standing upright? C. C. Steiner and others have suggested incisor measurements to a facial plane such as N–A; however, patients do not use artificial constructs such as Frankfort horizontal or the facial plane to evaluate their upper incisors. Cephalometrics serves as a general guide for evaluating the axial inclination of incisors, but a better guide would perhaps be to look at the soft tissue contours of the gingivae and labial surfaces of the upper incisors, since these are probably what patients are evaluating when they look at their incisors. If there is a different incline between the gingivae (from soft tissue point A) to the gingival margin and a tangent to the labial surface of the incisors, the incisors will not be attractive.

In the process of sequential treatment planning, once the anteroposterior position of the incisors is established and the arch widths determined, arch form and dimension can be finalized, and the upper and lower arches can be synchronized for proper overjet.

6
Chapter

The Treatment Midline

Now that we have sequenced the skeletal changes and established the treatment plane of occlusion and the upper and lower arch forms, the next step is to determine the treatment midline. In doing so, initially we will assume symmetrical tooth sizes between the right and left sides, and later we will include information on tooth size discrepancies.

The decision of where to place the midline is important not only for esthetic considerations, but also because it will determine the position of the posterior teeth. If the midline is moved to the right or to the left, dramatic tooth movement may be required asymmetrically in the posterior segments. Three factors determine a treatment midpoint: (1) the facial midline, (2) the incisor–apical base midpoint, and (3) the posterior midpoint. Each of these factors will be discussed in turn.

Midpoints, midlines, and midsagittal planes require some explanation. Each dental arch at the level of the occlusal plane will have a treatment midpoint, where the incisors are placed. A perpendicular line from this occlusal plane–treatment midpoint intersection represents the treatment midline. With the addition of another posterior point, the treatment midplane, or midsagittal plane, is formed. Similarly, facial midpoints, facial midlines, and a midsagittal plane can be identified for the entire skull.

The Facial Midline

By definition, the facial midline is one that looks good to the face. A number of methods can be used to establish a facial midline. Various points (landmarks) can be identified from the frontal headfilm, the frontal photographs, or the clinical exam, some of which are shown in Fig 6-1. Additional landmarks, such as crista galli, the intermaxillary suture, and hard tissue pogonion, can be seen on the headfilm. If these points happen to fall along the same line, the establishment of a facial midline is simple. Unfortunately, this does not always happen. One reason, of course, is the presence of a genuine asymmetry. Often, the lack of correspondence between points is an artifact caused by (1) an inability to visualize the structures, (2) head rotation in the cephalostat, (3) soft tissue flexibility, or (4) an inexact technique. Moreover, a common clinical procedure for connecting the points—soft tissue nasion, subnasale, and soft tissue pogonion—can give variable results even when repeated by the same orthodontist.

Some authors have proposed constructing additional landmarks by identifying bilateral structures and determining the midpoint between them. Figure 6-2a shows that selecting a midpoint between lateral structures creates midpoints that

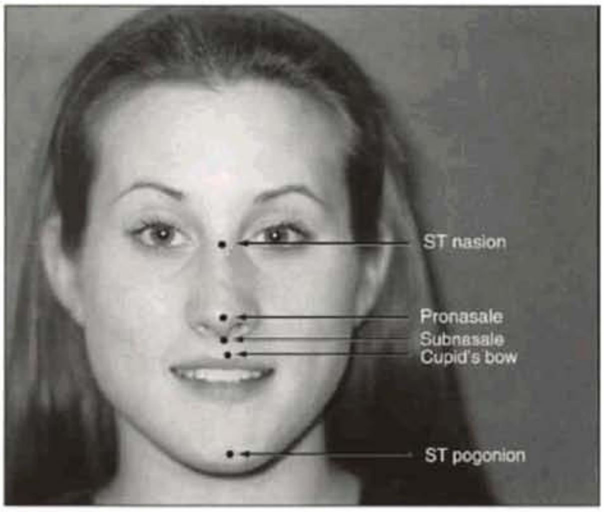


Fig 6-1 Soft tissue midpoints: Landmarks in the midface are established based on the clinical examination and an oriented photograph. (ST = soft tissue.)

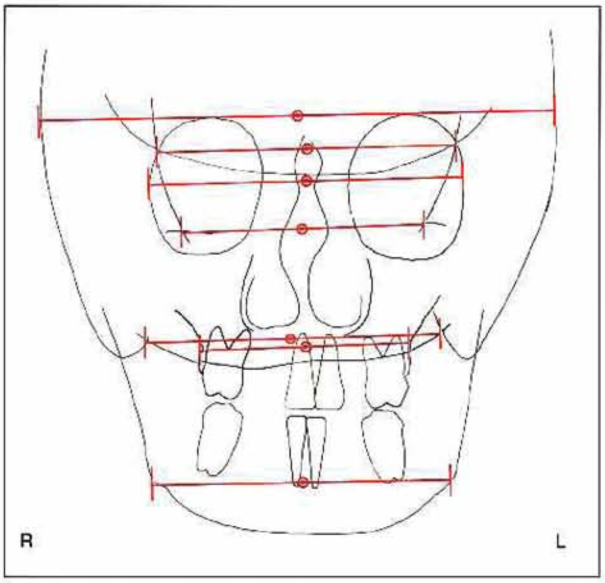


Fig 6-2a Bisecting a line that connects corresponding bilateral landmarks may be invalid since absolute symmetry between right and left does not exist. Note the variation in the midpoints, which prevents formation of a facial midline.

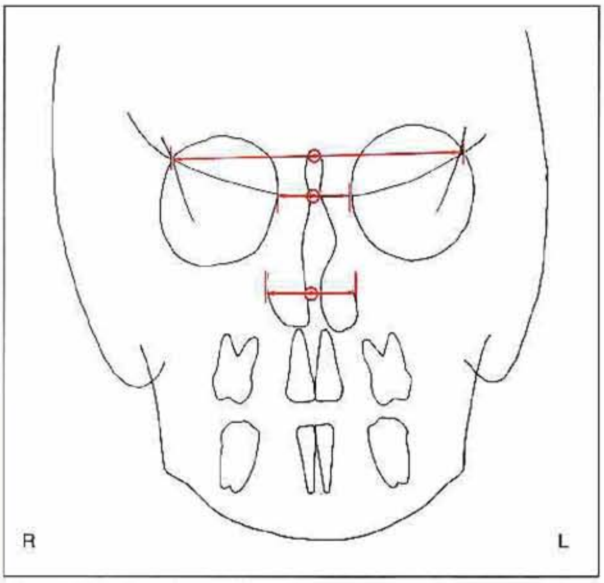
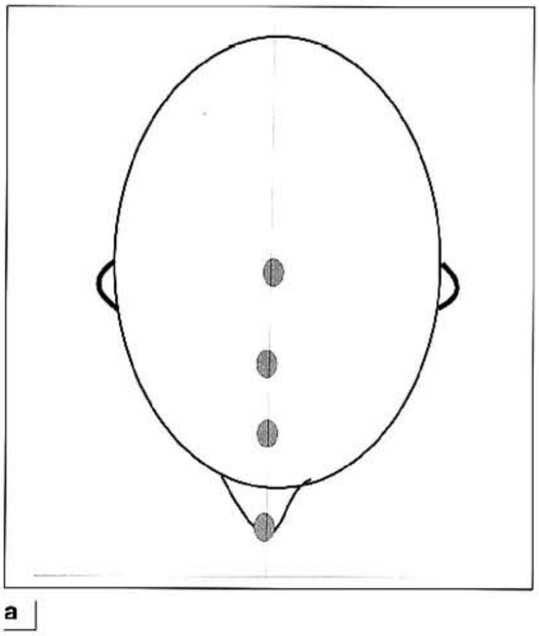
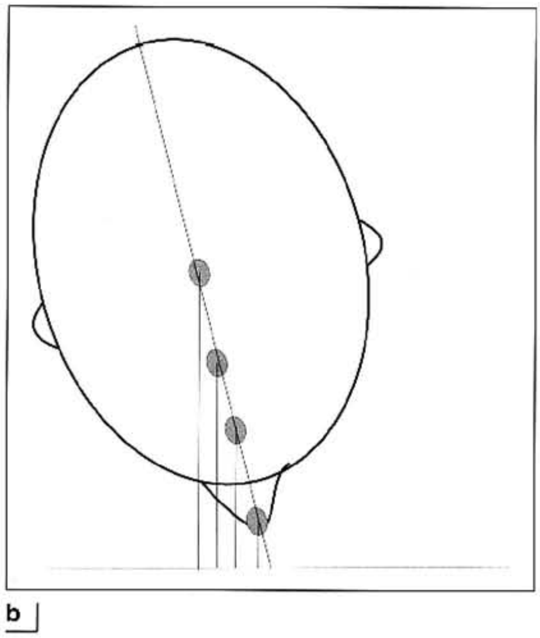


Fig 6-2b Bisecting a line that connects corresponding bilateral landmarks closer to the center of the face reduces variation in the location of the midpoints. Alignment of the three midpoints allows for the construction of a facial midline.

Fig 6-3 Rotation of the head produces an artificial asymmetry in photographs and posteroanterior headfilms. a, A symmetrical head with proper orientation. All midpoints are projected along the same line. b, The same symmetrical head shown in 6-3a is rotated. Midpoints furthest from the radiographic film are displaced laterally.

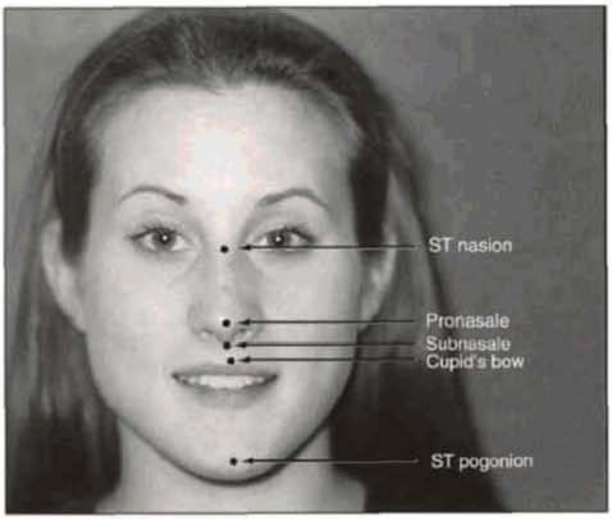




are not always in alignment and cannot be used satisfactorily to construct a facial midline even for relatively symmetrical patients. The closer bilateral structures are to the center of the face, the smaller the variation is in the midpoints as determined by a bisector (Fig 6-2b). There are many other reasons why bilateral structure midpoints on a posteroanterior film can be invalid. Faces are usually asymmetrical; that is, one side is usually wider than the other. When a symmetrical head is rotated about a vertical axis, an artificial asymmetry is produced because the landmarks most commonly used are not located in the same X-Z plane. A symmetrical head can produce an asymmetrical posteroanterior film if the head is improperly oriented (Fig 6-3a). Any rotation of the head distorts the observed or constructed midpoints, with the greatest discrepancy noted at landmarks furthest from the film (Fig 6-3b).

Another method for determining the facial midline is to establish a horizontal plane (line) from skeletal structures and to construct a perpendicular line from a midpoint landmark. There are two problems with this method. The first is the difficulty of determining which landmark or constructed point to use, and the second problem is that any small variation in the horizontal plane can produce a rather large deviation in the facial midline. Figures 6-4a and 6-4b illustrate how the facial midline changes with the selection of different horizontal planes.

The patient in Fig 6-5 has a small dental midpoint discrepancy. After selecting a midpoint between the two orbits, a perpendicular bisector was constructed to two different lines, one based on the right and left latero-orbitales and the other on an interpupillary line, resulting in two different facial midlines. Although the midline based on



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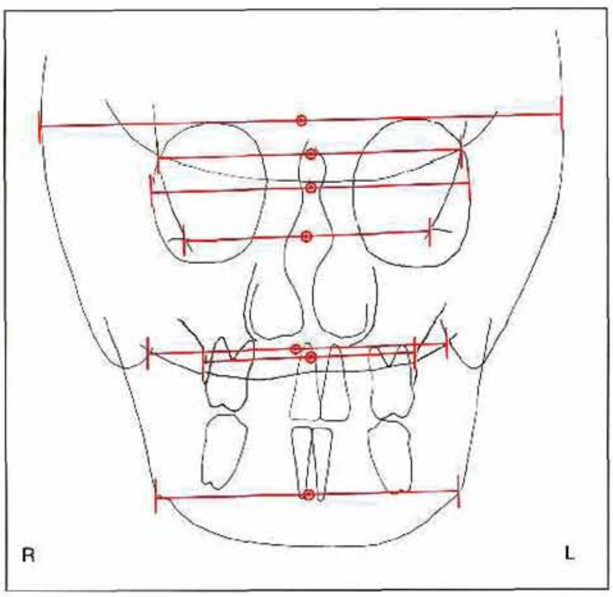

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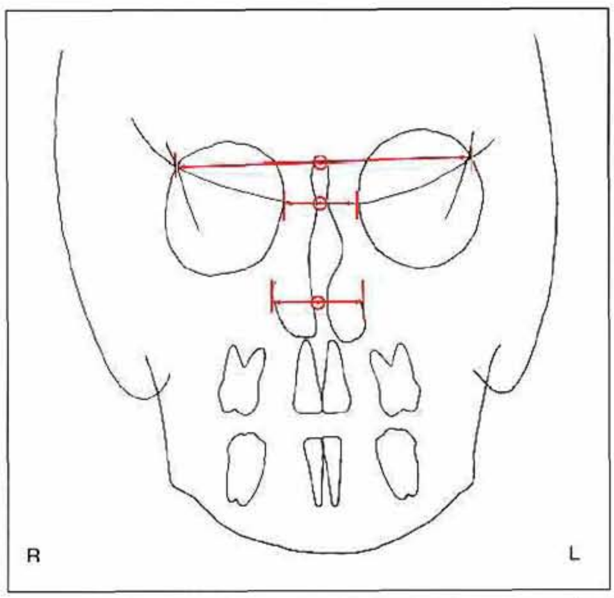

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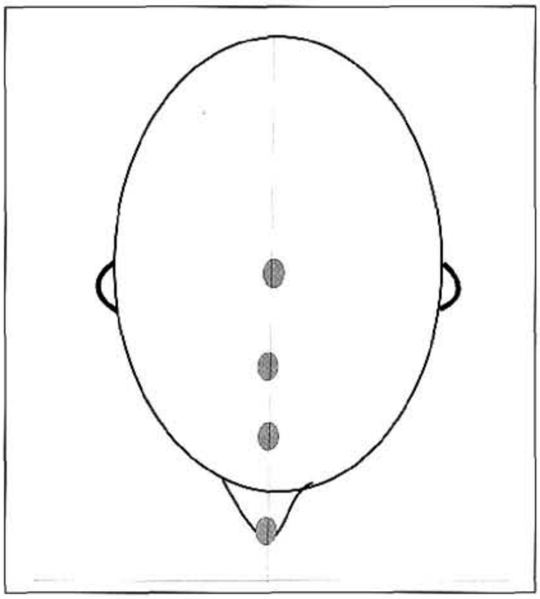

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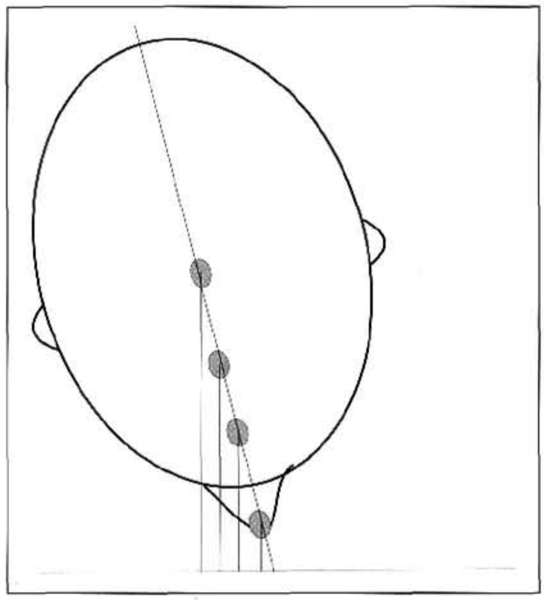

b

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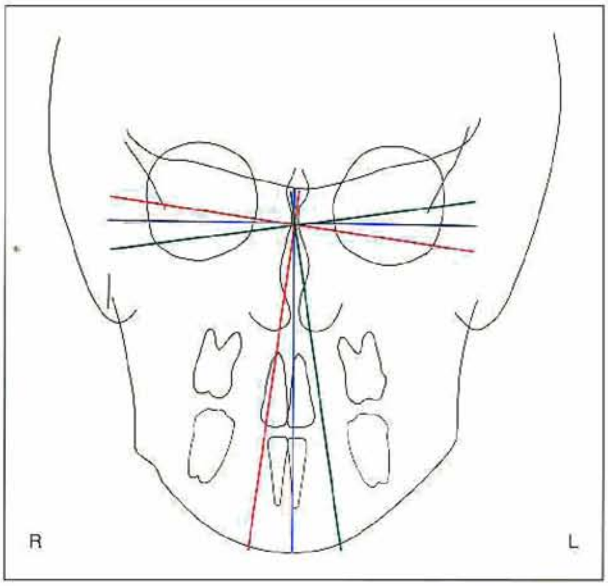

Fig 6-4a When establishing a facial midline by constructing a perpendicular to a horizontal plane from a midpoint, one must be sensitive to small variations in the horizontal plane. In this diagram, a midpoint between the orbits is selected. Rotation of the horizontal reference line produces a significant change in the facial midline at pogonion.

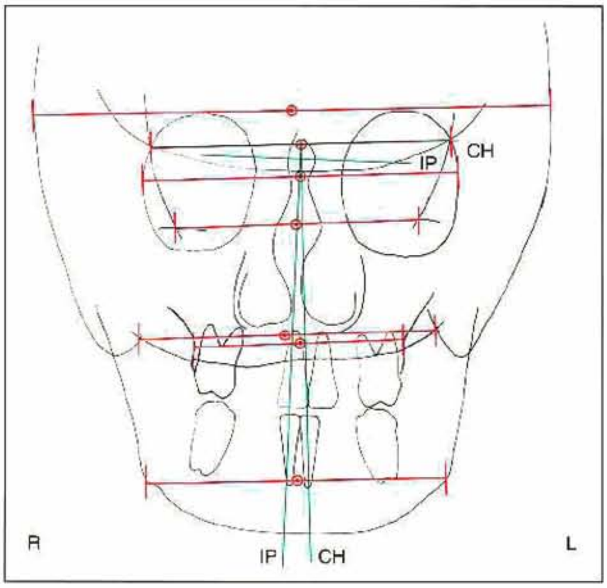

Fig 6-4b Two horizontal lines were established: a cranial horizontal (CH) line and an interpupillary (IP) line. A facial midline established as a perpendicular bisector to the cranial horizontal shows good incisor midpoint. A facial midline established as a perpendicular bisector of the interpupillary line places the upper incisor midpoint and pogonion to the patient's left. Neither facial midline may be correct; the perpendicular bisector of the CH, however, appears to be more reasonable.

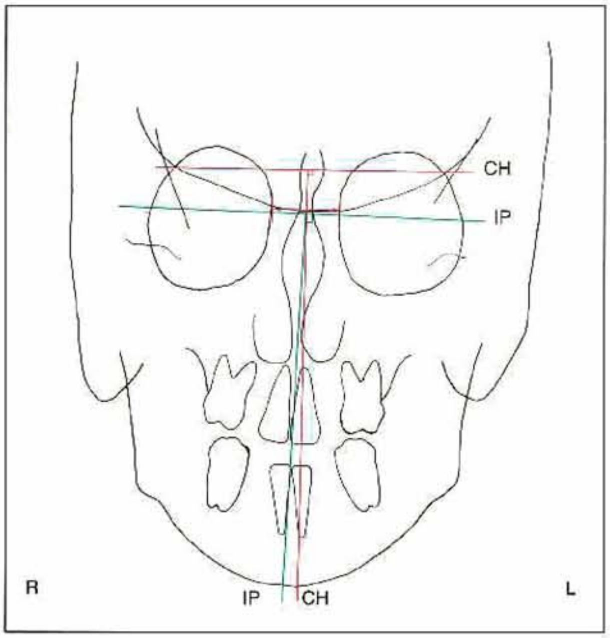

Fig 6-5 Unlike the patient shown in Fig 6-4b, here the perpendicular bisector of the interpupillary line is more reasonable than a perpendicular bisector of the cranial horizontal. Arbitrary perpendicular bisectors can lead to an improper determination of the treatment incisor midpoints.

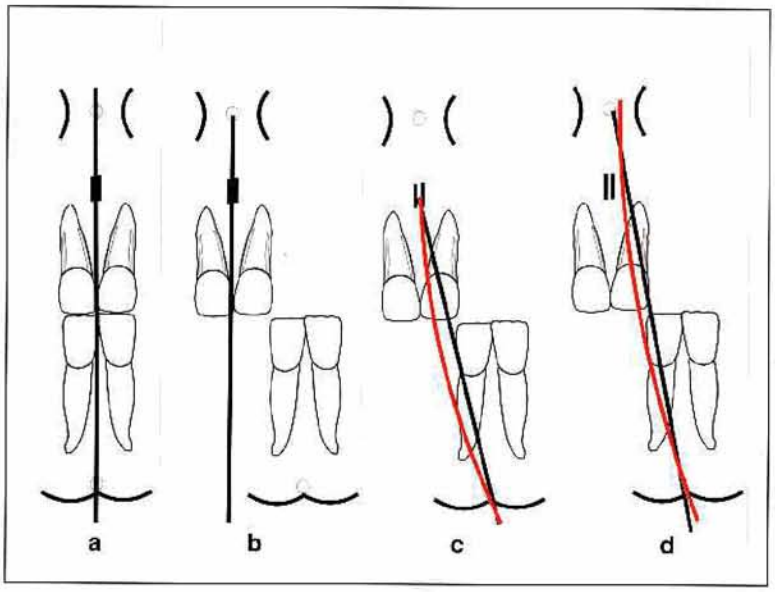

Fig 6-6 Midpoint correspondence and selection of a facial midline. a, Nasion, intermaxillary suture, and pogonion are in alignment. A facial midline can be constructed between these three points. b, Using upper facial midpoints to construct the facial midline requires maximum lateral movement of the lower incisors. c, Connecting the intermaxillary suture and pogonion requires equal movement of the upper and lower incisors. A curved line, or mid-arc (red), minimizes the upper incisor movement. d, Connecting nasion and pogonion requires maximum upper incisor movement. The facial midlines shown are artificial constructs and may not meet the esthetic needs of the patient.

the interpupillary line seems more reasonable, this is merely coincidental since, as shown in Fig 6-4b, this line is highly variable and unpredictable. Other skeletal horizontal lines could have been drawn through other cranial and facial landmarks, but they too are not parallel. Using perpendicular bisectors as constructs is dangerous since it can lead to improper incisor treatment midpoint determinants, poor esthetics, and unnecessary and difficult tooth or jaw movements.

The landmarks nasion, intermaxillary suture, and pogonion are in alignment in Fig 6-6a. A facial midline could be constructed by simply connecting these three points, and it might be valid to place the incisor midpoints on this line after considering other esthetic factors. But how does the orthodontist establish a facial midline when the midpoints nasion, intermaxillary suture, and pogonion are not in alignment? One possibility is to consider orthognathic surgery to align the midpoints. However, many discrepancies are not severe enough to warrant surgery, and even for those that are, the patient may decline. In Fig 6-6b, pogonion is to the left of the intermaxillary suture and nasion. A facial midline could be constructed between the intermaxillary suture and pogonion (Fig 6-6c) or between nasion and pogonion (Fig 6-6d). Each would result in a different facial midline and hence a different incisor treatment midpoint.

Figures 6-6b through 6-6d are not as simple to treat as the constructs might suggest. Placing the incisor midpoints on the upper facial midline (Fig 6-6b) ideally requires orthognathic surgery; otherwise, considerable lateral movement of the lower incisors is needed. Figures 6-6c and 6-6d require progressively less movement of the lower incisors. A curved line further reduces the lateral movement of the lower incisor to the right. The choice of a facial midline is, then, a value judgment that depends on the artificial constructs chosen.

In some patients, should one consider not even using the facial midline? Perhaps using a curvature that fits the midpoints is a better solution. The curve would vary of course, depending on the landmarks used and the radius of the curvature. In some patients, then, the facial midline is not a straight line but rather a curve; hence, the facial midline could be referred to as the facial mid-arc.

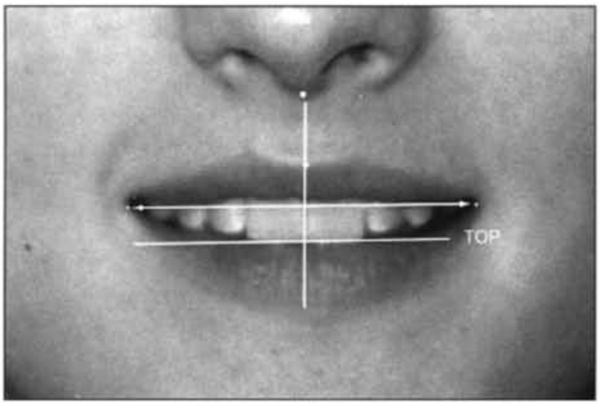

Fig 6-7 Patient determination of the dental midpoint. The patient uses horizontal planes such as a line connecting the corners of the mouth (chelion to chelion), the transverse occlusal plane, and the upper and lower lip horizontals. Soft tissue midpoints (cupid's bow, center of the philtrum, and subnasale) are projected onto the horizontal planes and are visually compared to the incisor midpoints. (TOP = treatment occlusal plane.)

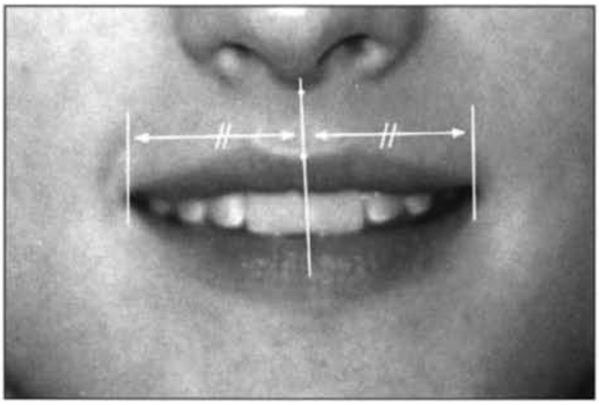

Fig 6-8 The patient can judge the incisor midpoints by checking the distance from the midpoint to the corners of the mouth. An equal number of teeth should be exposed bilaterally.

To summarize, the selection of a facial midline, while useful, is subject to many inaccuracies. In many respects, choosing a facial midline is highly subjective, ie, a "judgment call," and its limitations should be appreciated. Patients can easily sense if their incisor midpoints are not aligned although as orthodontists we might wonder how they can do this. Certainly they are not placing a length of dental floss over their face or making measurements from a headfilm or establishing a facial midline. Most likely they are evaluating their midpoints relative to soft tissue structures. For example, they note whether the midpoint of the upper incisors lies directly under the philtrum (Fig 6-7) or under cupid's bow, and whether the corners of the mouth are positioned over the same teeth on both sides of the mouth (Fig 6-8).

The patient in Fig 6-9a has a dental midpoint discrepancy in which the lower dental midpoint is to the right of the upper midpoint. A faulty treatment plan included the extraction of the maxillary right first premolar and movement of the upper dental midpoint to the right. The discrepancy in incisor midpoint placement was obvious to the patient, who noted the lack of alignment of the upper dental midpoint to midpoint soft tissue landmarks such as subnasale and cupid's bow as well as the premolar located closer to the right corner of the mouth than to the left (Fig 6-9b). The upper and lower dental midpoints are in reasonable alignment after space closure, but not in harmony with the overlying soft tissue morphology (Figs 6-9c and 6-9d). The patient did not have to establish a facial midline from soft tissue nasion to soft tissue pogonion to draw this conclusion.

The occlusal view shows the midpoint skewed to the right (Fig 6-9e). A commonly used guide in the X_1-Z_1 (occlusal) plane, which is often helpful in establishing a treatment midpoint, is the median palatal raphe. Its limitations include errors in the construction of a single line since curvature may be present and correlation to other soft tissue facial structures is lacking. Relative to the raphe, the upper dental midpoint is far to the right.

The establishment of a facial midline and midsagittal plane is important when orthognathic surgery is planned since soft tissue and skeletal midpoints must coincide. In the nonsurgical patient with a skeletal asymmetry, one should not use artificial constructs of a facial midline but rather other esthetic factors to position the dental midpoints.

Fig 6-9 Incorrect treatment midpoint. a, Before treatment: The lower incisor midpoint is located to the right of the upper incisor midpoint. The upper incisor midpoint is in approximate alignment with cupid's bow and other soft tissue structures. The treatment occlusal plane is the red line. b, During treatment: An upper right first premolar was removed, causing the upper dental midpoint to move to the right. This unesthetic result was very obvious to the patient. Note the distances of the canines to the corners of the mouth and the position of the incisors to cupid's bow. c, Frontal intraoral photograph, before treatment. d, Frontal intraoral photograph, after treatment. e, Occlusal view showing the incisors displaced to the right of the median palatal raphe.

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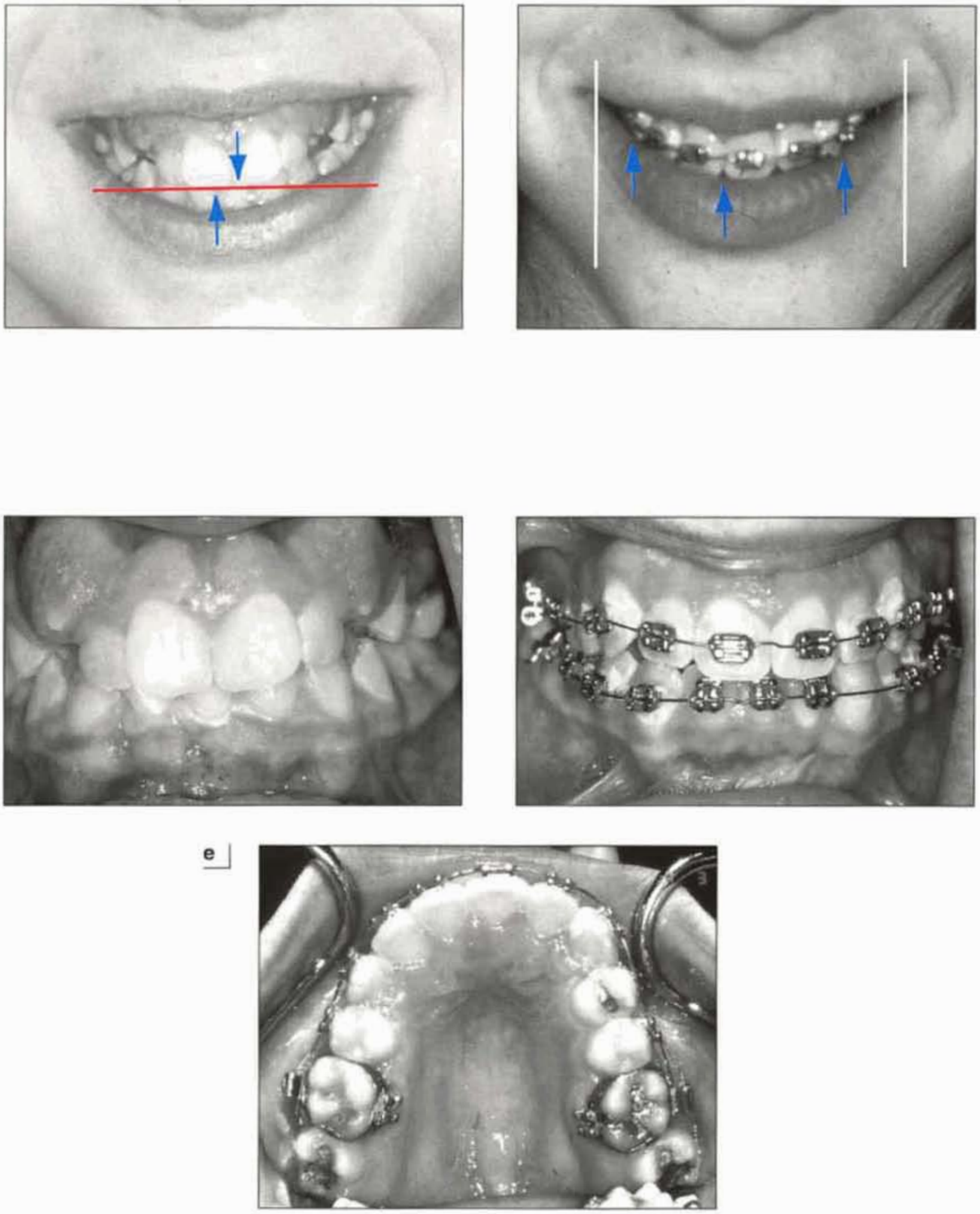
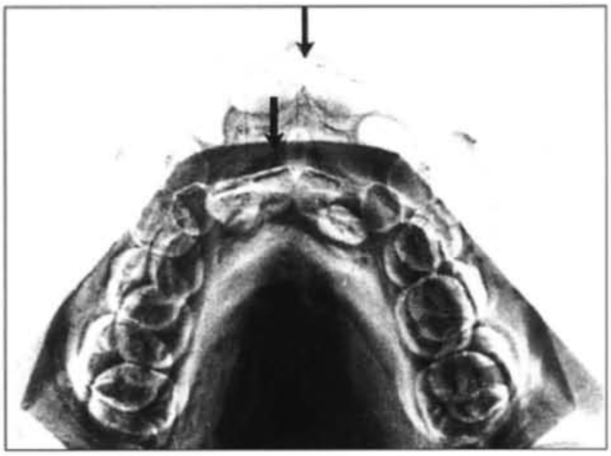


Fig 6-10 Apical base midpoints. a, The center points between the roots of the incisors are averaged to construct the upper and lower apical base midpoints on the posteroanterior headfilm. b, The apical base midpoints are projected at 90 degrees to the occlusal plane and shown on the occlusogram.

a

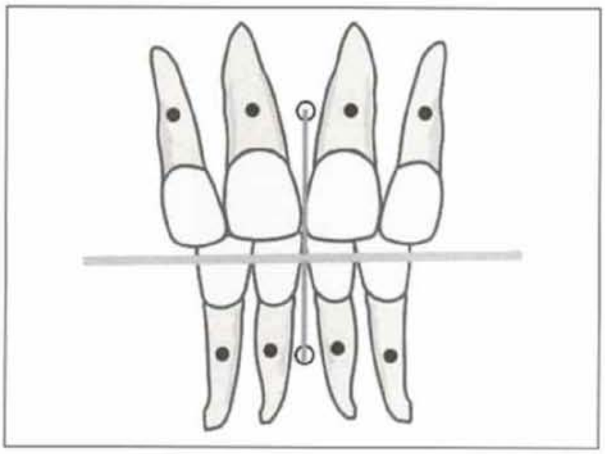


b

Incisor–Apical Base Midpoints

In the sagittal view (Y-Z plane), measuring the apical base points, A and B, relative to the occlusal plane, is helpful in determining the anteroposterior denture base discrepancy. The farther apart they are, the more difficult it is to correct the Class II or Class III malocclusion. Similarly, in the frontal view (Y-X plane), measuring the apical base midpoints relative to the transverse occlusal plane allows one to determine the transverse denture base discrepancy. Definite landmarks such as points A and B on the lateral headfilm are not available on the frontal headfilm. Therefore, it is necessary to construct the apical base midpoints by placing a point at approximately the midpoint of each of the incisor roots occlusogingivally and then finding their average mediolaterally (Fig 6-10a). These two midpoints, one in the maxilla and one in the mandible, are known as the upper and lower apical base midpoints. The rationale for selecting these points is biological: forces exerted by muscles, transseptal fibers, and orthodontic appliances tend to tip teeth about a point, generally near the root center as measured from the cementoenamel junction to the root apex. Apical base midpoints serve as useful functional landmarks in planning the position of the treatment midpoint and midline (Fig 6-10b). A perpendicular line from the upper and lower apical base midpoints is extended to the respective treatment occlusal plane. Ideally, the upper and lower perpendicular lines coincide at their intersection with the occlusal plane, a sign that no transverse apical base discrepancy or skeletal discrepancy of the anterior bony landmarks exists in the middle of the maxilla and mandible (Fig 6-11a). A transverse apical base discrepancy exists when the upper and lower apical base midpoints do not coincide (Fig 6-11b). Transverse apical base discrepancies present a challenge in treatment.

Fig 6-11 Apical base midpoints. a, Perpendicular lines extended from the apical base midpoint to the treatment occlusal plane coincide when there is no transverse apical base midpoint discrepancy. b, Transverse apical base midpoint discrepancy. The lower apical base midpoint is positioned to the right of the upper apical base midpoint.



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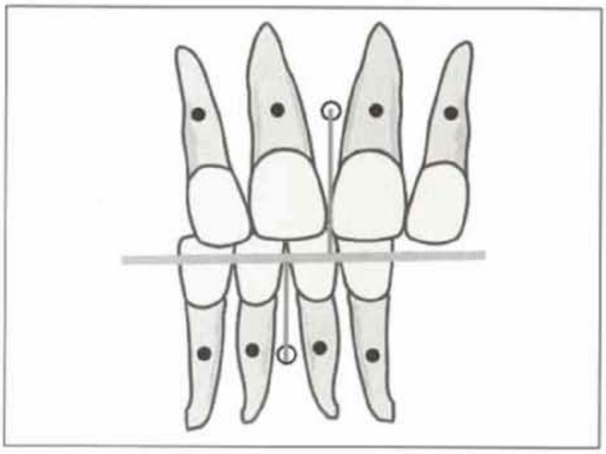

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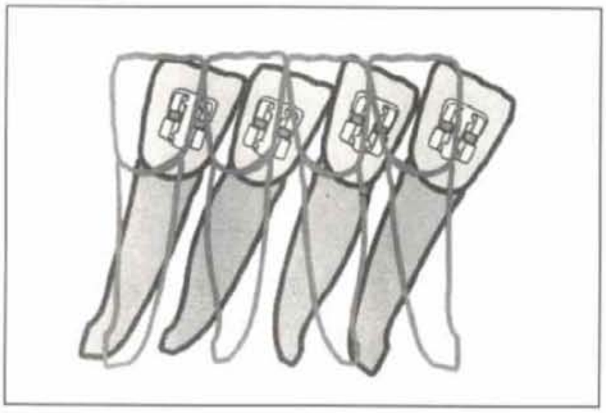


Fig 6-12 Normalizing axial inclinations. The incisor midpoints can be used as a guide to the position of the apical base midpoints. Mentally uprighting and normalizing mesiodistal axial inclinations positions and locates the apical base midpoint between the central incisors in their new location.

In some patients, orthognathic surgery is required to achieve coincidence of the apical base midpoints. For less severe apical base midpoint discrepancies or for patients who wish to avoid surgery, the choice of treatment midpoints is complicated. Asymmetric mechanics, minimalization of lateral translation, and anchorage control are all required to reduce side effects.

Apical base midpoints can be estimated without the posteroanterior headfilm. During the clinical examination, root midpoints can be determined by observation and palpation.

Since an apical base discrepancy is measured to the transverse treatment occlusal plane, the cant of this plane is critical. (This topic is discussed in more detail later in the chapter.) Small variations in upper and lower apical base midpoints may be artifacts caused by obscured roots or projections if the head is turned in the cephalostat. Another way of identifying a transverse apical base discrepancy is to mentally normalize the axial inclination of the incisors. In Fig 6-12, the mandibular incisors lean visibly to the left; that is, the right incisors have mesioangular

Fig 6-13 Dental midpoint discrepancy with no transverse apical base difference. Mentally normalizing the lower incisors produces upper and lower dental midpoint correspondence.

and the left incisors have distoangular axial inclinations. Rotating the teeth around the centers of their roots to normalize their axial inclinations moves the incisor midpoint to the right, which would be the location of the apical base midpoint at the level of the treatment occlusal plane.

Coincident apical base midpoints

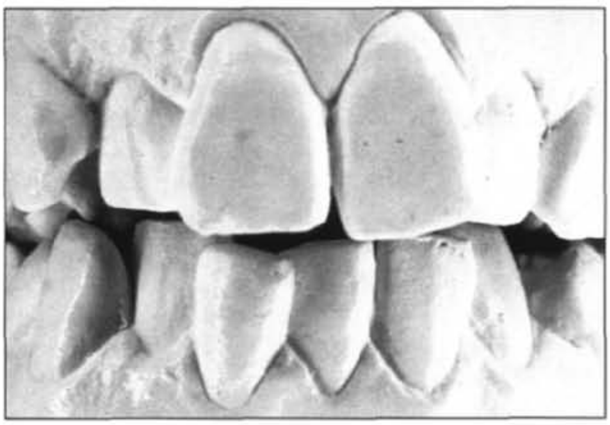
Many incisor midpoint discrepancies are dental in origin. Teeth may have drifted during eruption or because of premature tooth loss. The dental origin of these incisor midpoint discrepancies is readily diagnosed since no apical base midpoint discrepancy exists. The lower incisor midpoint in Fig 6-13, which is to the left of the upper incisor midpoint, is the result of tipping toward the left of the lower incisors. Mentally normalizing the axial inclinations of these lower incisors about their root centers would make the upper and lower incisor midpoints coincide. That the mandibular left canine is blocked out to the labial is insufficient evidence to diagnose the incisor midpoint discrepancy; for instance, the lower left buccal segment could be forward. Mentally normalizing the axial inclinations of the lower incisors, which lean to the left, helps to classify the problem as primarily dental in origin. Incisor midpoint discrepancies without an apical base midpoint discrepancy are usually

Fig 6-14 No transverse apical base midpoint discrepancy. Lower incisors were tipped to the left to correct the midline discrepancy. a, Frontal view of teeth, before treatment. b, Frontal view of teeth, after treatment.

a

b

Fig 6-15 Upper left central incisor leans to the left. Normalizing the upper axial inclinations by tipping around the root midpoints shows little transverse apical base midpoint discrepancy. a, Study casts, before treatment. b, After treatment using tipping mechanics with single forces only.



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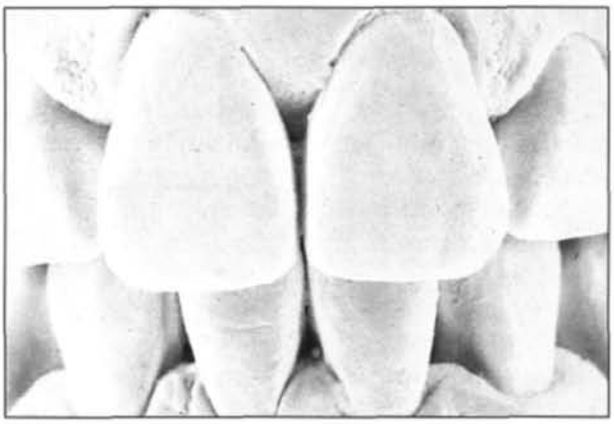


b

simple to correct—and may even be self-correcting—during treatment with symmetrical mechanics in the rest of the arch combined with incisor drift due to transseptal fibers.

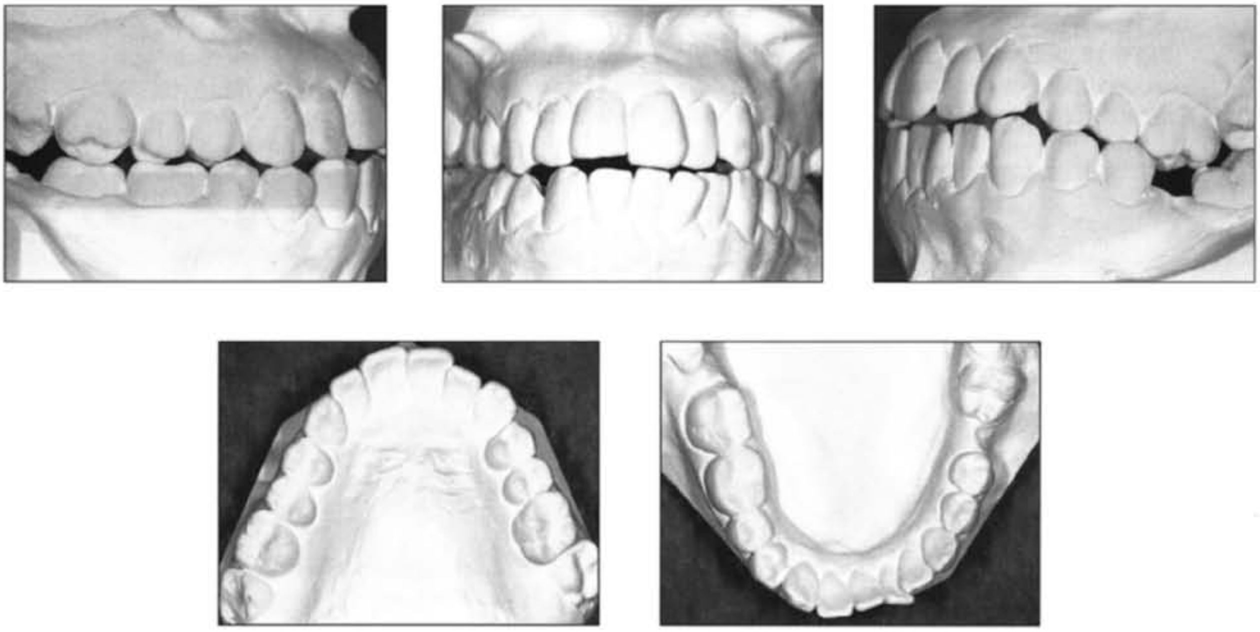
The patient shown in Fig 6-14a has a dental midpoint discrepancy. The upper incisor is well positioned in relation to the soft tissue midpoints. Mentally uprighting the lower incisors to the left corrects the midpoint discrepancy. Treatment mechanics must allow freedom of tipping; any restraint can produce root movement to the right and minimal midpoint correction. Figure 6-14b shows the midline correction by a tipping movement.

The incisor midpoint discrepancy shown in Fig 6-15a involves both the upper and lower incisors. The upper incisors are tipped mainly to the left. Mentally normalizing the axial inclinations produces incisor midpoint correspondence. The problem was corrected by simple tipping rather than translation of the teeth along an arch wire (Fig 6-15b).

a

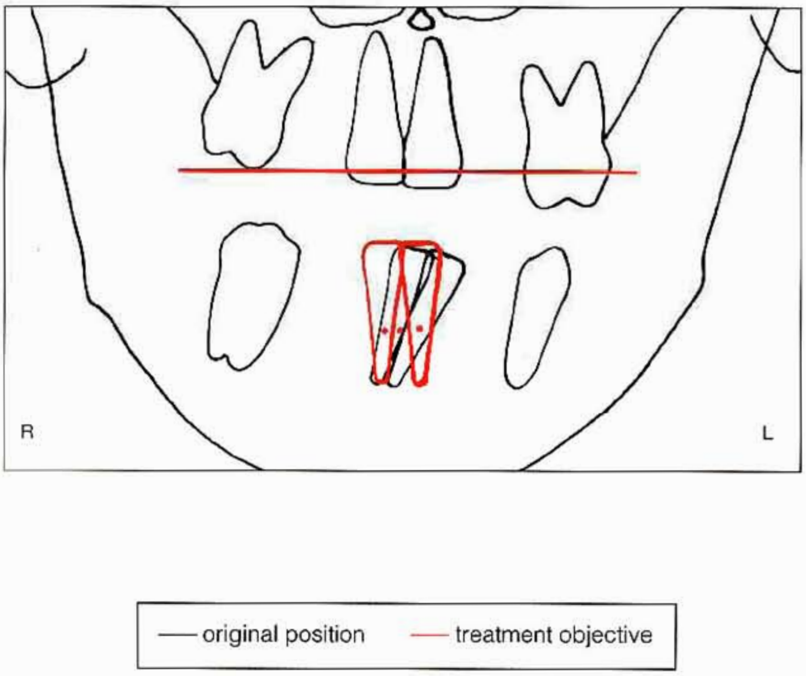
Fig 6-16 Patient MR. Incisor midpoint discrepancy. The lower incisor midpoint is positioned to the left of the upper incisor midpoint. a, Frontal photograph before treatment. b, Study casts. Compare axial inclinations of the right and left canines and premolars. The lower teeth are tipped to the left as a result of a prematurely extracted left first molar. c, Posteroanterior headfilm tracing. The lower incisors are normalized about the root center of each incisor and no apical base midpoint discrepancy is present.

b



Patient MR exhibited a relatively symmetrical face (Fig 6-16a). The interpupillary and transcommissural lines show a small divergence, and there is an incisor midpoint discrepancy (Fig 6-16b) which, though large, is diagnosed as a dental rather than a skeletal problem. The posteroanterior headfilm shows no transverse apical base discrepancy when measured to the existing occlusal plane (Fig 6-16c). Treatment to the apical base midpoint required tipping of the mandibular incisors to the right. This incisor midpoint deviation is associated with the removal of the mandibular left first molar several years earlier. A comparison of the mesiodistal axial inclinations of the right and left canines and premolars shows that the left teeth are tipped distally. Furthermore, the left canine is tipped labially more than the right. Mentally normalizing the axial inclinations would result in upper and lower incisor midpoint coincidence.

c



Apical base midpoint discrepancies

When a transverse apical base discrepancy between the two arches is found, both diagnostic and treatment problems may result. For example, should one treat to the upper or to the lower apical base midpoint—or to a different midpoint entirely? Do suitable mechanics exist for the lateral translation of incisors, or must some tipping of the incisors result? How much of a transverse discrepancy must be present before orthognathic surgery is required?

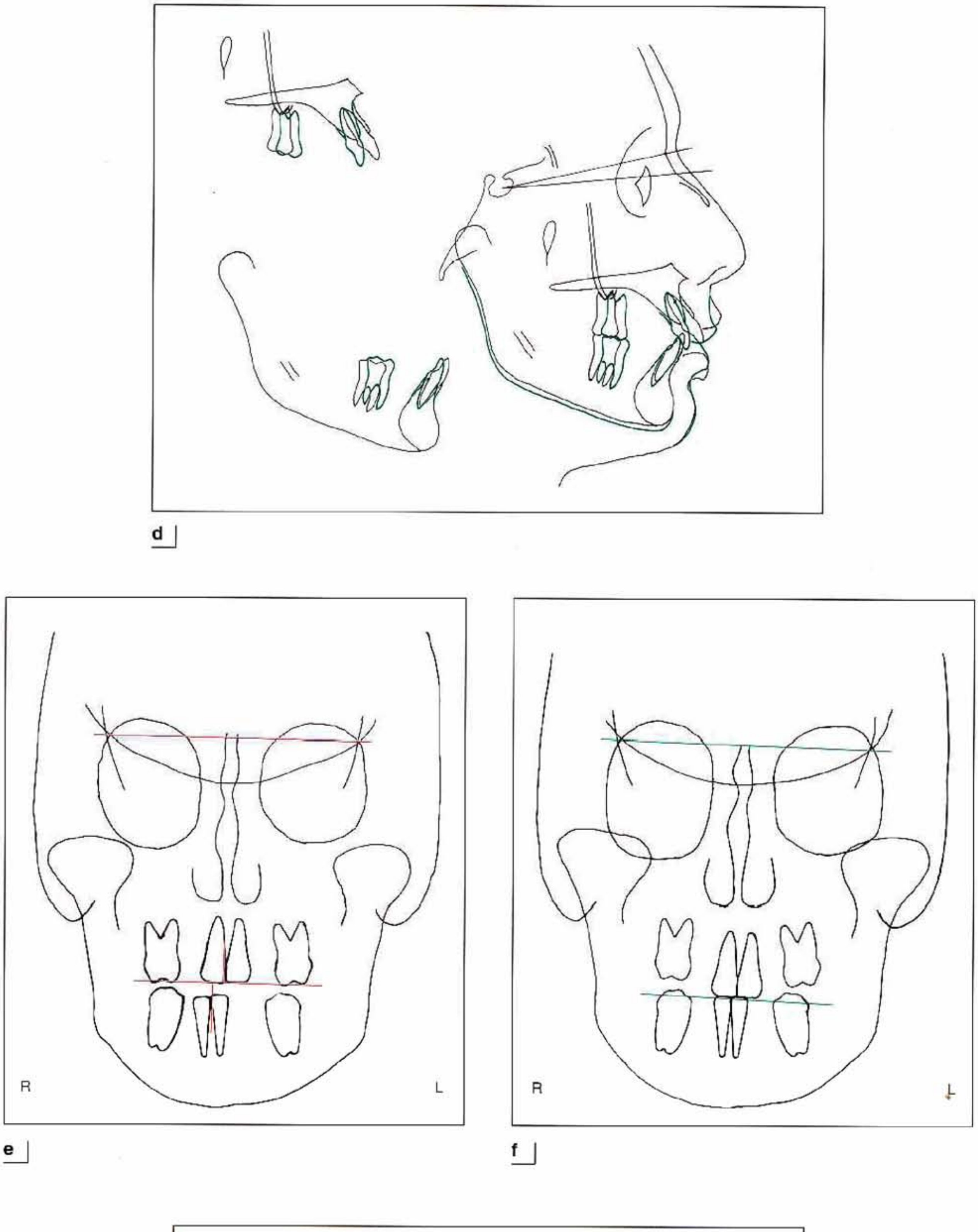
Patient CC has a Class II malocclusion on the right side and an incisor midpoint discrepancy (Fig 6-17). The overjet and large interlabial gap make lip closure difficult. A large transverse apical base midpoint discrepancy is present; the lower apical base midpoint is to the right of the upper apical base midline, which is in alignment with the soft tissue midpoint landmarks. The lower apical base midpoint is associated with pogonion, which is positioned to the right along with the Class II occlusion. The patient was treated by symmetrical extractions in the upper arch (upper first premolars) and asymmetrical extractions in the lower arch (lower left first and right second premolars). The apical base midpoint discrepancy is less than the incisor midpoint discrepancy since the lower incisors lean visibly to the right (Figs 6-17b and 6-17e). Treatment involved both uprighting and translating the mandibular incisors to the left (Figs 6-17c and 6-17f). The small incisor midpoint discrepancy present at the end of treatment could have been eliminated by tipping the lower incisors more to the left and protracting the buccal segments more on the right. The lateral headfilm shows good control of the vertical dimension (Fig 6-17d). The retraction of the upper incisors facilitated lip closure. In addition to the asymmetrical extractions, asymmetrical mechanics were employed to achieve differential protraction of the lower posterior teeth during space closure. Recognizing the practical limitations of lateral translation, it is helpful in this type of patient to angle the lower incisor brackets so as to facilitate tipping of the lower incisors to the left.

Fig 6-17 Patient CC. Incisor midpoint discrepancy with a Class II malocclusion on the right and a Class I malocclusion on the left. The lower apical base midpoint is to the right of the upper apical base midpoint. a, Frontal facial photographs, before and after treatment. b, Study casts, before treatment. c, Study casts, after treatment. d, Lateral cephalometric tracings, before and after treatment. e, Tracing of posteroanterior headfilm, before treatment. f, Tracing of posteroanterior headfilm, after treatment. Translation of lower incisors to the left was required for midpoint correction.

a

b

c



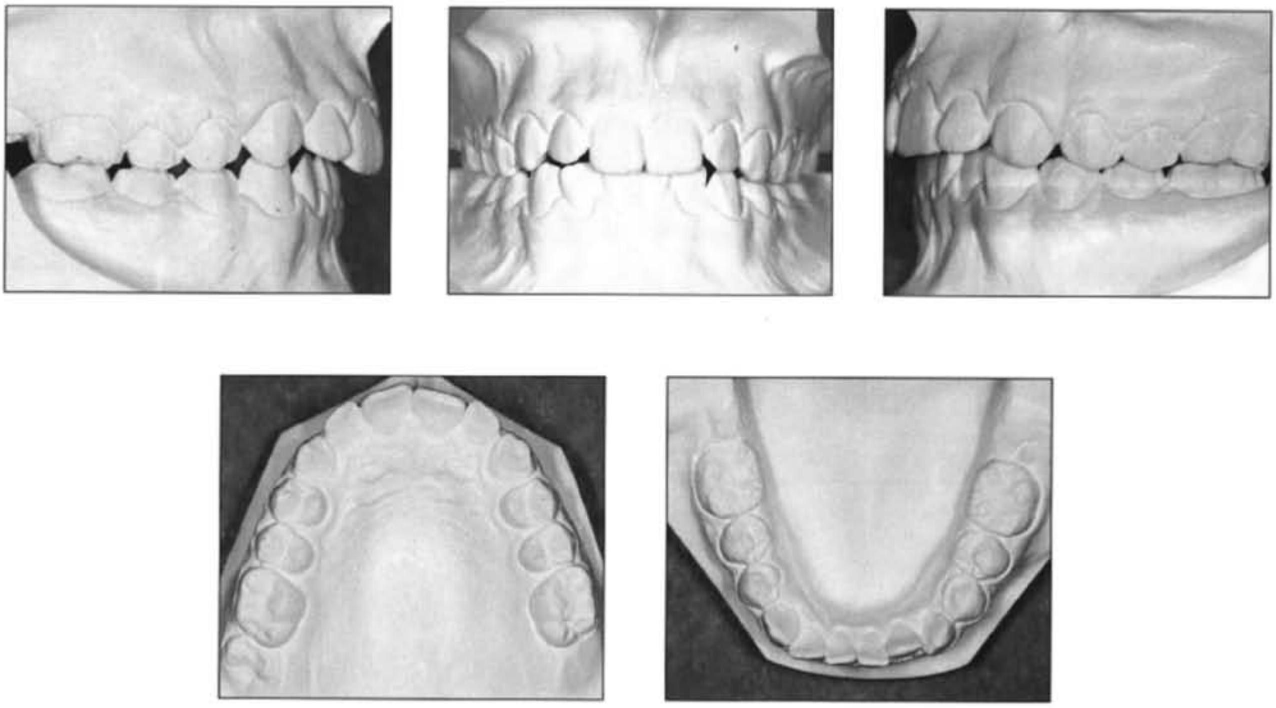
— original position — treatment objective — treatment outcome

Fig 6-18 Patient JMM. Apical base midpoint discrepancy with a Class II malocclusion on the right and a Class I malocclusion on the left. The incisor midpoint discrepancy does not reflect the transverse apical base midpoint discrepancy since the lower incisors are tipped to the right. a, Facial photographs, before and after treatment. b, Study casts, before treatment. c, Study casts, after treatment. d, Tracing of posteroanterior headfilm, before treatment, showing apical base midpoint discrepancy. e, Occlusogram. The treatment midpoint is the facial midpoint. Red arrow, facial midpoint; blue arrow, apical base midpoint; green arrow, posterior midpoint.

a

Patient JMM presented with a unilateral Class II malocclusion with only a small incisor midpoint discrepancy (Fig 6-18). The reason for the small incisor midpoint discrepancy in the presence of a larger apical base midpoint discrepancy is the convergent (compensatory) axial inclinations of the lower incisors, which lean visibly to the right (Figs 6-18b and 6-18d). The upper incisor midpoint was well positioned in relation to the soft tissue midpoint structures, and was therefore maintained (Fig 6-18e). The upper right first and left second premolars were removed; the left buccal segment was protracted more than the right to produce a symmetrical Class II molar occlusion (Fig 6-18c). The desirability of maintaining stable but atypical axial inclinations is here illustrated by maintaining the slight tipping of the lower incisors, which is usually acceptable to the patient. This principle can be extended to apical base midpoint discrepancies with symmetrical mesiodistal inclinations at the beginning of treatment. As shown in this patient, teeth can be tipped to simulate the natural situation, particularly in the lower arch, which does not show as much as the upper. Greater angulation of the lower brackets to maintain the lower incisor midpoint and axial inclinations would have improved the outcome.

b



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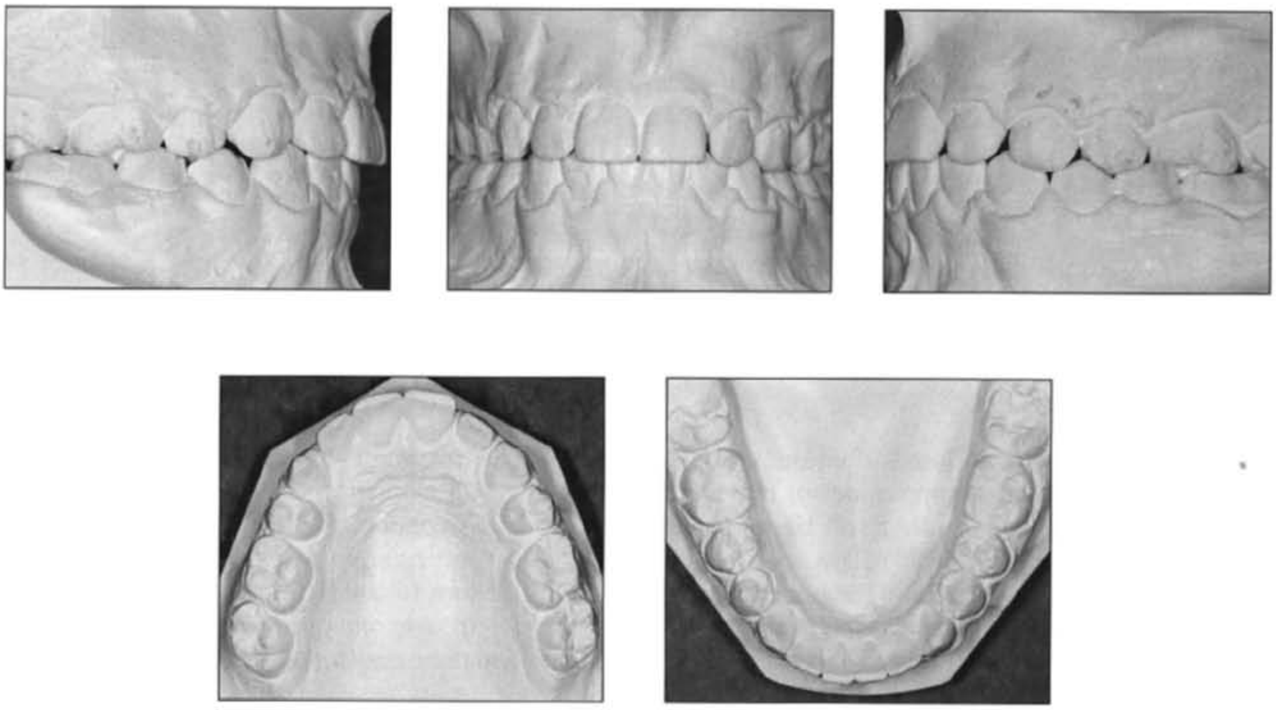

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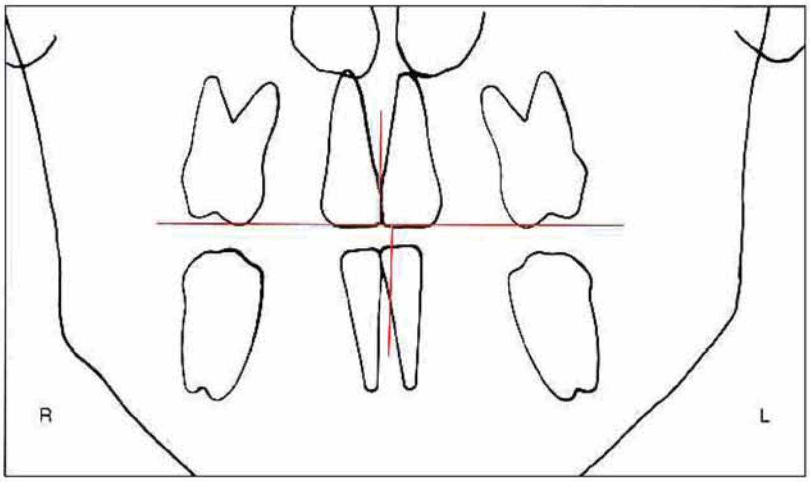
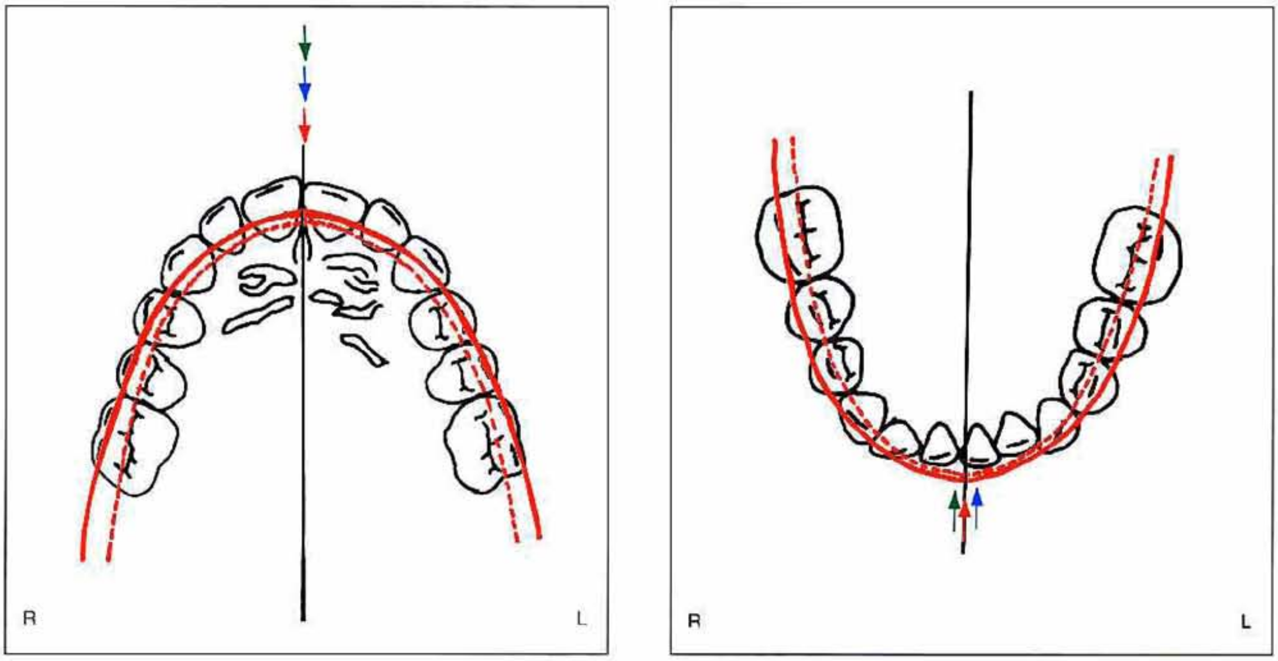




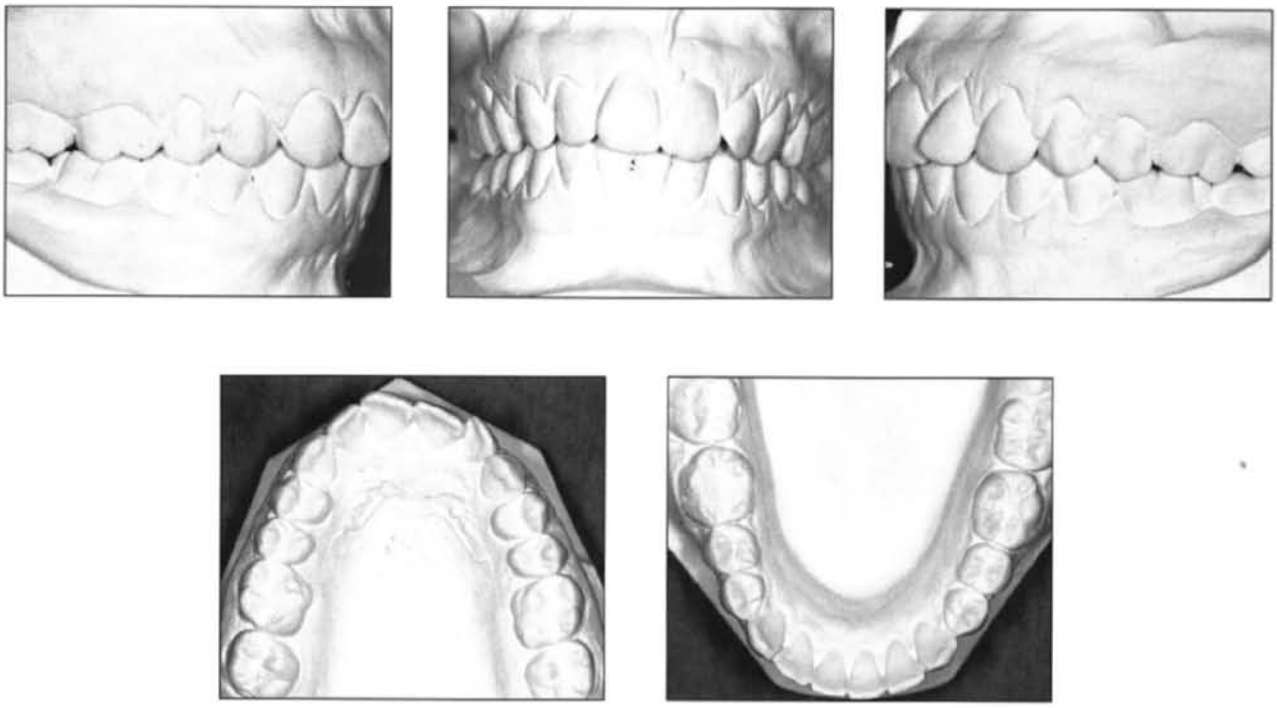
e

Patient SC, who had a Class II, division 2 malocclusion (Fig 6-19a), had an upper incisor midpoint that was aligned with the other soft tissue facial midpoint structures (Fig 6-19d). The upper right first premolar was extracted and the upper incisor midpoint was moved to the right to coincide with the lower incisor midpoint (Figs 6-19b and 6-19c). Although the final occlusion and intercuspation were good, treating to the lower incisor midpoint presented an esthetic problem. A better solution in this type of patient would have been to tip back the lower left posterior segment and move the lower incisors to the left. In some instances the extraction of only one premolar in the lower arch to allow midline correction and two premolars in the opposing arch may be required.

Fig 6-19 Patient SC. The upper incisor midpoint was treated to coincide with the lower incisor midpoint. The upper and lower incisor midpoints coincide at the end of treatment, but both are to the left of the facial midpoints, resulting in poor esthetics. a, Frontal facial photographs, before and after treatment. b, Study casts, before treatment. c, Study casts, after treatment. d, Tracing of posteroanterior headfilm, before treatment.

a

b



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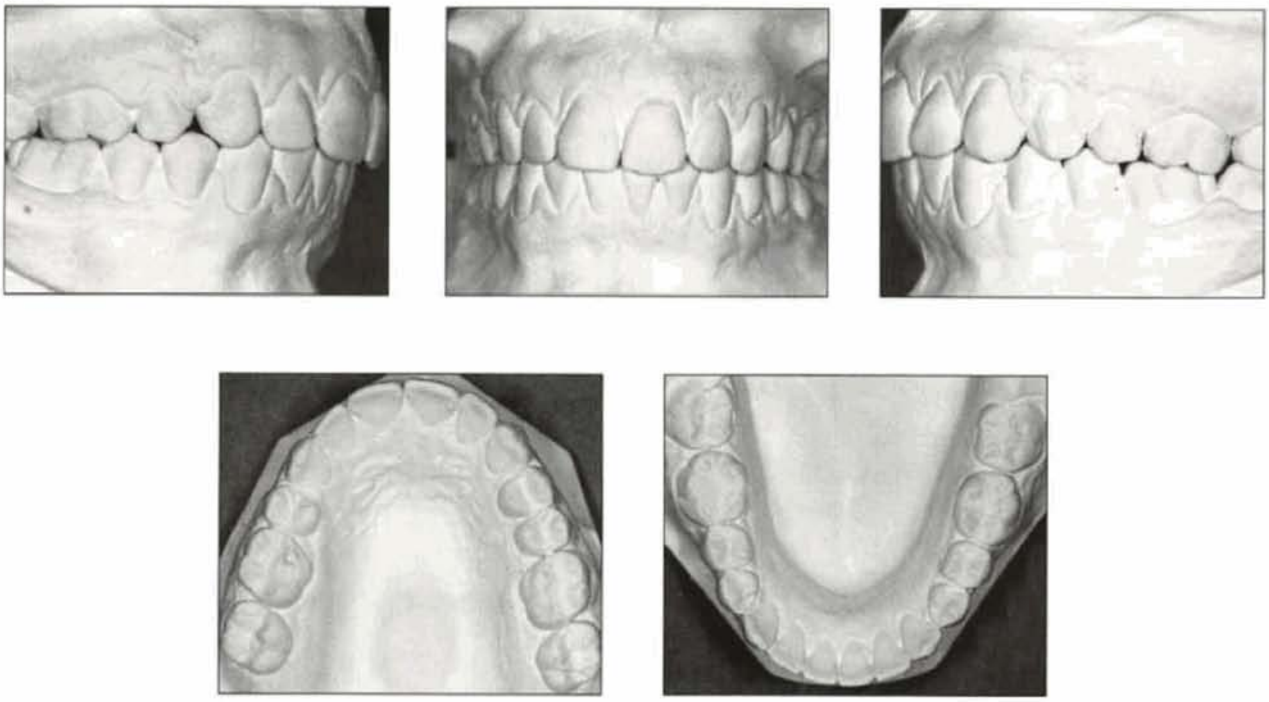

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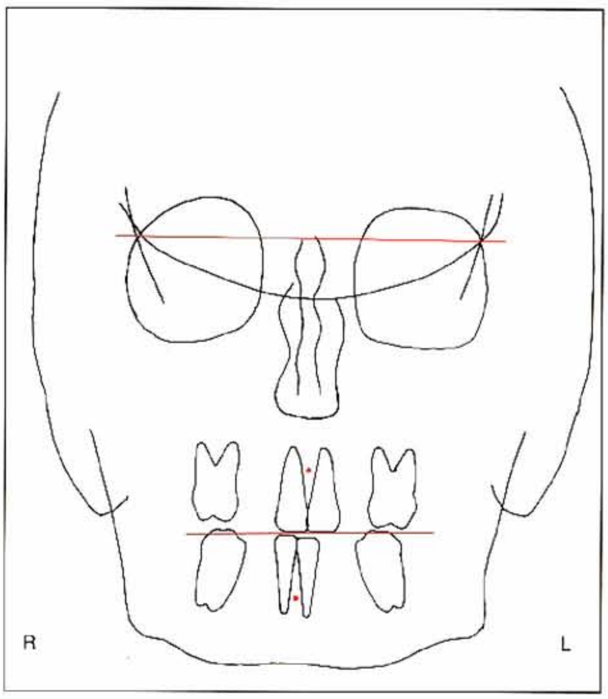
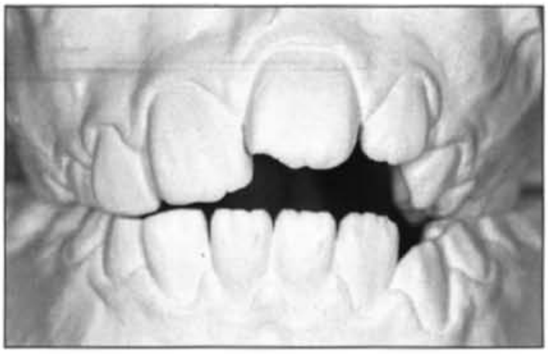


Fig 6-20 Patient RA. Upper apical base midpoint discrepancy produced by the distal position of the upper central incisor root. a, Study casts, before and after treatment. b, Tracing of posteroanterior headfilm, before treatment, showing transverse apical base discrepancy. c, Leveling of the upper arch created moments that displaced the upper arch to the right, revealing the apical base discrepancy. d, Posteroanterior headfilm tracing after treatment. To correct the transverse overjet and incisor midpoint discrepancy, crisscross elastics and an asymmetrical headgear were used: These produced an undesirable canting of the transverse occlusal plane.

a



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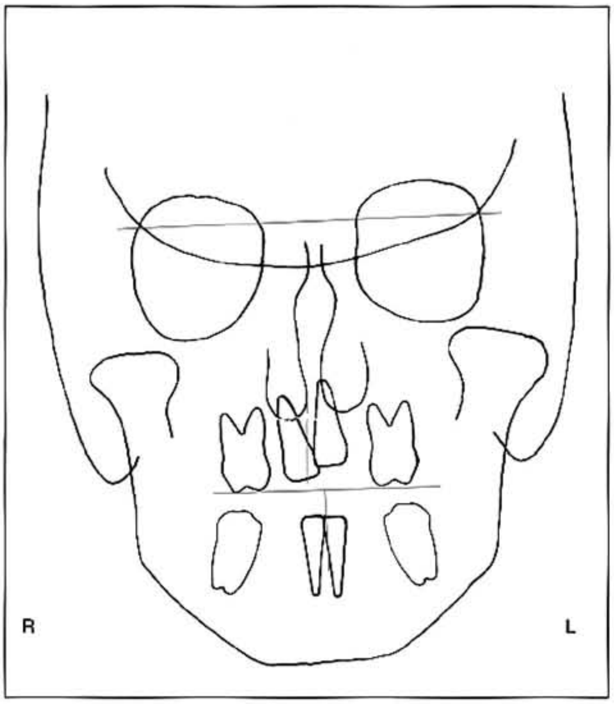
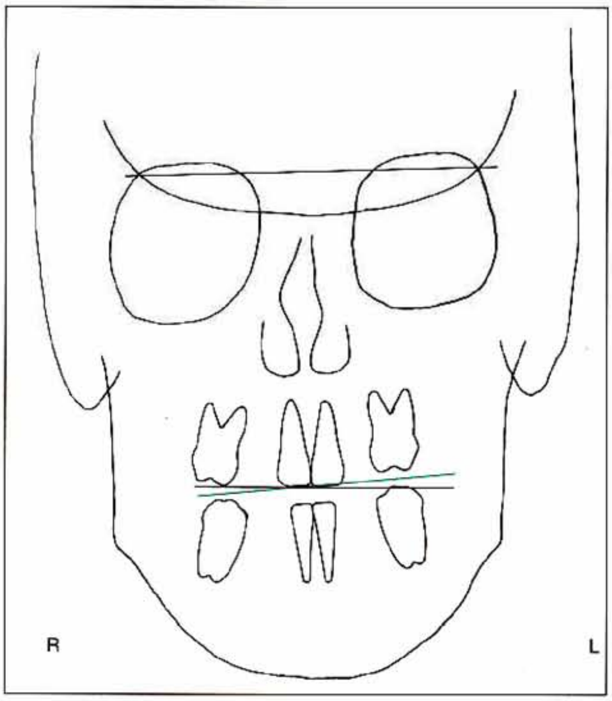


Patient RA exhibited a small incisor midpoint discrepancy (Fig 6-20), which was worsened by a severe apical base midpoint discrepancy (Fig 6-20b). The lower apical base midpoint was coincident with the soft tissue midpoint structures; the upper apical base midpoint was to the right and associated with a mesially inclined right central incisor. Brackets were placed at average heights and angulations to the upper teeth. After leveling of the arches, the transverse apical base discrepancy expressed itself; the upper incisor midpoint moved to the right and led to an increase in the right canine overjet (Fig 6-20c). The moments created by leveling the right incisor displaced the

c



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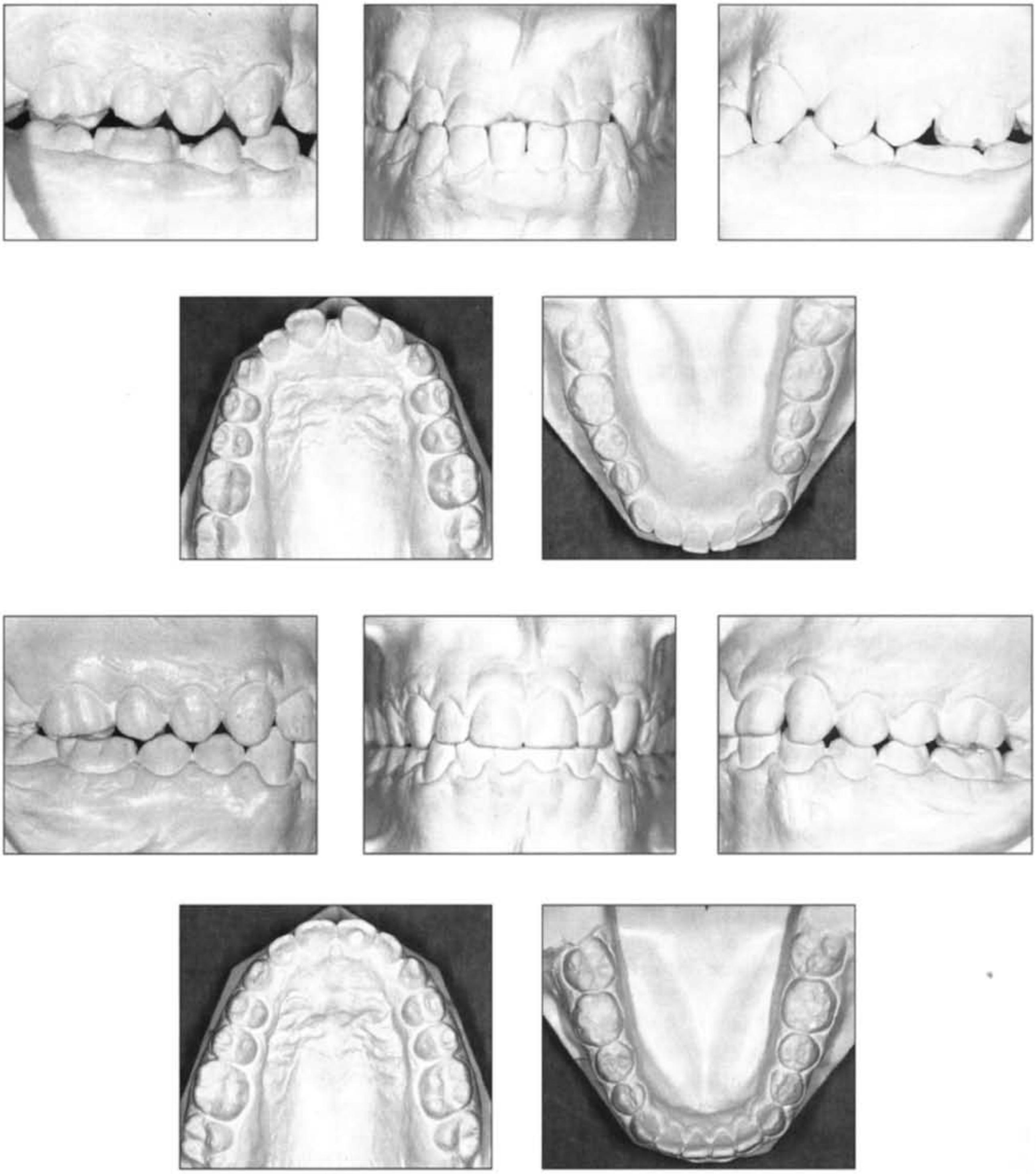
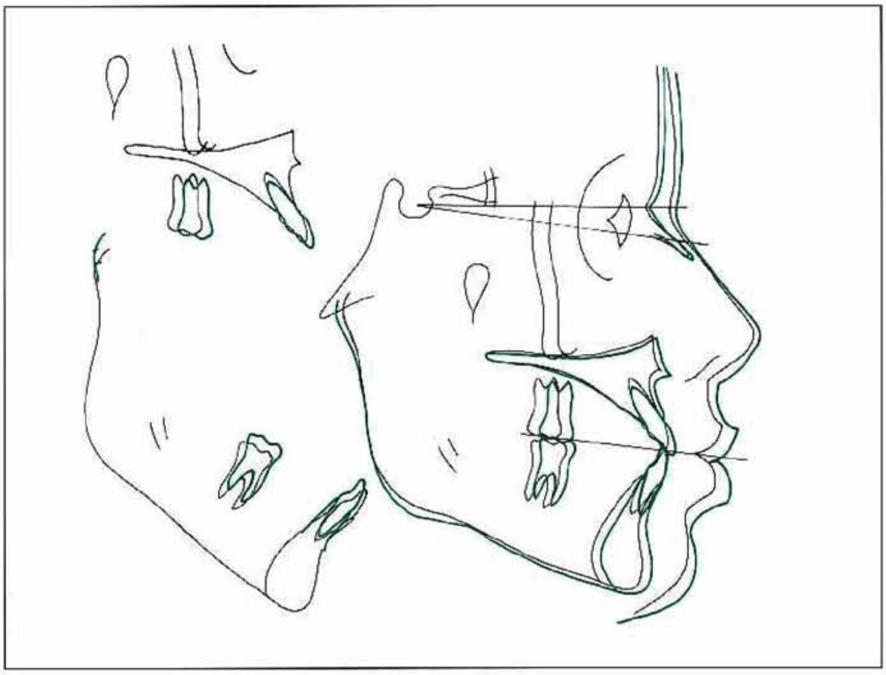
entire arch laterally to the right. Anterior criss-cross elastics and asymmetrical headgear were applied to the upper arch. The lateral forces to the left altered the cant of the transverse occlusal plane, with the right side inclining down to the right and producing an unsightly appearance (Fig 6-20d). This problem could have been avoided if the transverse apical base discrepancy had been recognized and better anchorage had been used to move the root of the right central incisor mesially.

Apical base midpoints must be evaluated in centric relation; in centric occlusion the discrepancy can be better or worse. Patient CB had a shift of the mandible anteriorly and to the left (Fig 6-21). If treatment were planned from this position, difficult asymmetrical mechanics would be necessary. However, the orthodontist was aware of this mandibular shift and used symmetrical mechanics. The apical base midpoints nearly coincide at the end of treatment (Figs 6-21a, 6-21c, and 6-21d). Orthodontists are not always so fortunate: casts trimmed to an incorrect centric relation can lead to a greater midpoint discrepancy, complicating treatment considerably.

Fig 6-21 Patient CB. Symmetrical mechanics used during treatment corrected the midline discrepancy. A small transverse apical base discrepancy was present at the beginning of treatment. The study casts are trimmed in centric occlusion, which exaggerates the discrepancy since the mandible shifts to the left. a, Treatment study casts, before and after treatment. b, Tracings of the lateral cephalometric headfilm, before and after treatment. c, Tracing of the posteroanterior headfilm, before treatment. d, Tracing of the posteroanterior headfilm, after treatment.

a





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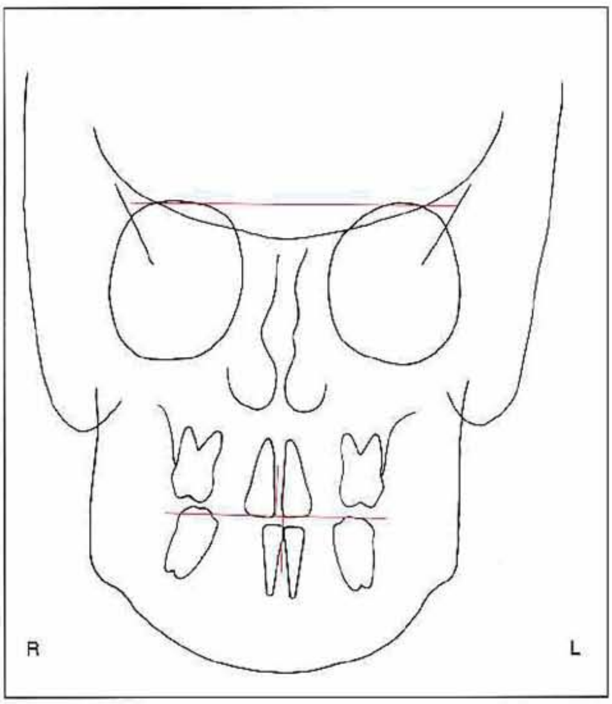

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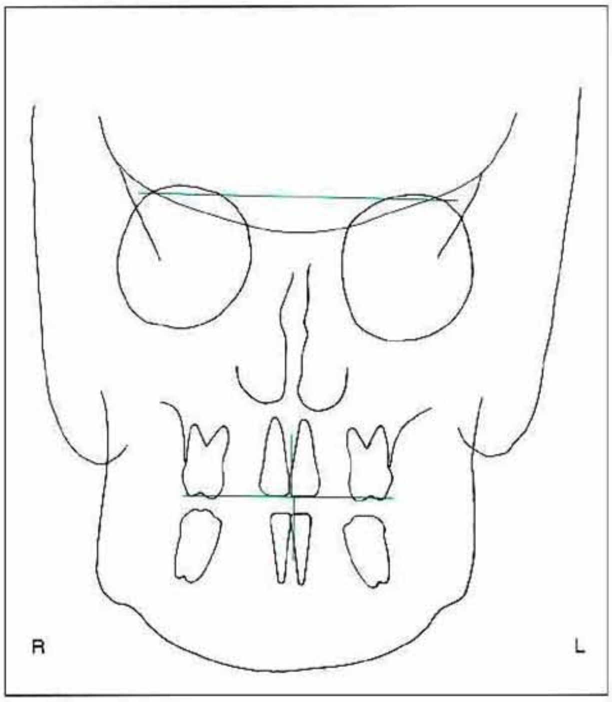

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— original position — treatment objective — treatment outcome

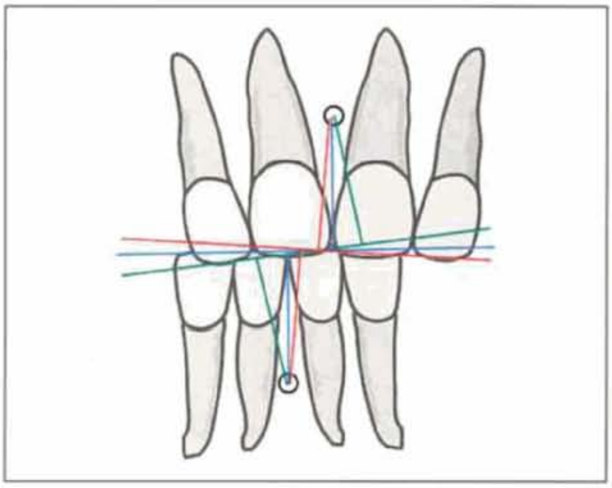


Fig 6-22 Apical base midpoint discrepancy is apparent from the treatment occlusal plane (blue). Rotating the plane clockwise (red) reduces the discrepancy and rotating it counterclockwise (green) increases the discrepancy.

Occlusal plane cant and midpoint discrepancies

If orthognathic surgery is planned, apical base midpoints can be related to a horizontal line such as the interpupillary or skeletal lines. In the nonsurgical patient, the orienting plane is the transverse treatment plane of occlusion, which must be accurately determined since small variations in its cant can have a dramatic effect on the magnitude of the apical base midpoint discrepancy. The diagram in Fig 6-22 shows a large apical base midpoint discrepancy in which the lower apical base midpoint is to the right of the upper. Rotating the transverse occlusal plane clockwise reduces this discrepancy and rotating it counterclockwise worsens it.

In the frontal view the transverse occlusal plane should be esthetic. It is typically parallel to the transcommissural line as well as to a line tangent to the lower lip. In asymmetrical patients, the transcommissural line may not be parallel to general facial horizontal lines. The transverse occlusal plane must also consider the vertical position of the teeth, particularly the right and left buccal segments. Holding a straight edge across the right and left sides of the study casts, differences can be noted and averaged. These lines are mentally transferred to the incisor region and compared with the plane established by esthetics. At the conclusion of the treatment-planning process, a single transverse treatment plane of occlusion is established to guide future mechanics and to identify the presence of a transverse apical base midpoint discrepancy. In a patient requiring orthognathic surgery that will alter the upper and lower treatment plane relationship, it is possible to have two transverse treatment planes of occlusion.

The posteroanterior headfilm should not be used to establish a transverse treatment plane of occlusion because structures such as molars may be difficult to see. Judgments about the posterior teeth should be made based on a survey of the casts. Once the transverse treatment occlusal plane has been established from the casts and the clinical exam, it can be transferred to a tracing of the posteroanterior headfilm.

The transverse treatment occlusal plane (line) might not be parallel to the other horizontal planes (lines) of the face (Fig 6-23). In the nonsurgical patient, this plane should be maintained if it is esthetic to the corners of the mouth. Of course, if severe discrepancy exists, orthognathic surgery would be the treatment of choice to achieve full horizontal plane parallelism.

What are the solutions to an apical base discrepancy using mechanotherapy alone? One approach is to translate incisors laterally if space can be made available, recognizing that anchorage could be lost in the process, resulting in a skewing of the arches. Therefore, if the apical base midpoint discrepancy is large enough—that is, over 3 mm—one must look to other solutions.

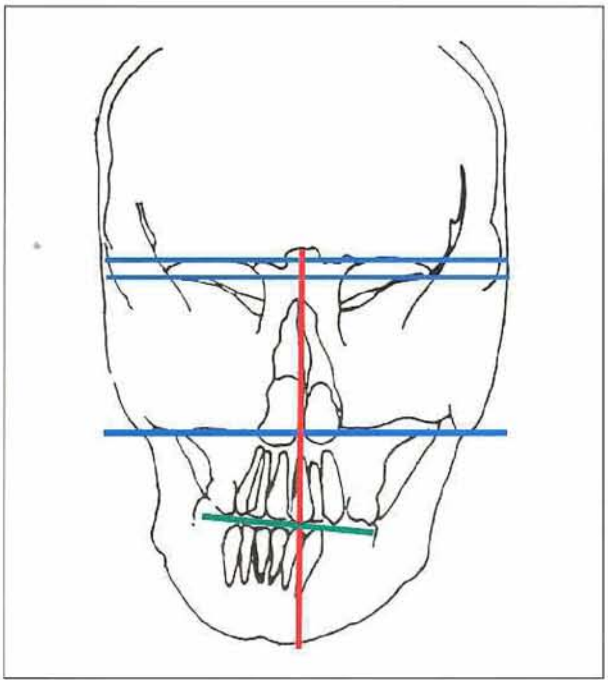


Fig 6-23 Tipped transverse treatment plane of occlusion. The treatment occlusal plane from the frontal view is not always parallel to other skeletal horizontal lines. Patients undergoing orthognathic surgery should have parallelism of these planes at the end of treatment. In the nonsurgical patient, the abnormal cant is often maintained since it usually parallels a line connecting the corners of the mouth.

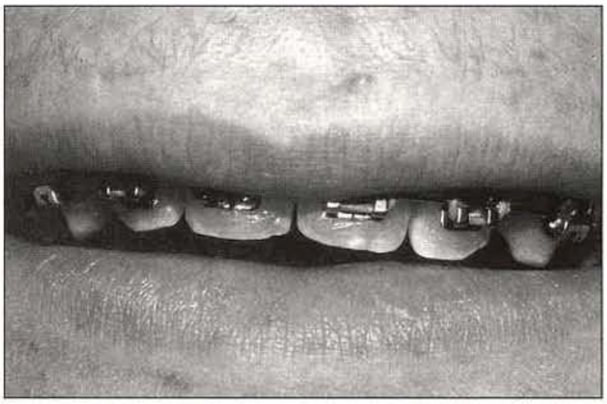


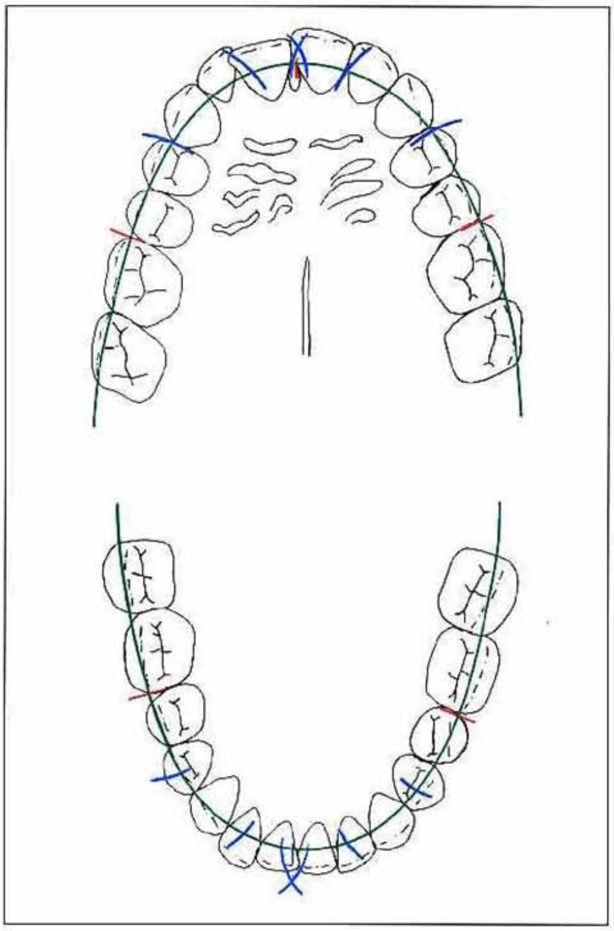
Fig 6-24 An abnormally canted upper transverse occlusal plane. The left side is lower than the right side. Patients readily see a canted plane, relating it to a line connecting the corners of the mouth or a line tangent to the lower lip.

A second solution is to use a simpler force system to tip the teeth so that the incisor midpoints of the arches will coincide. The disadvantage of this approach is that it may be unesthetic; however, tipping teeth a few millimeters may not be that obvious to the patient or even to the orthodontist, and smoothing of the incisal edges may further mask the problem. Many patients' incisors may have already compensated before treatment, and if so they will appear reasonably esthetic and will certainly be stable. A third approach is to alter the cant of the transverse occlusal plane; this is probably the least desirable of the solutions. With the lips apart it becomes obvious that the transverse occlusal plane is sloping down more on one side than the other, and this is both unsightly and very apparent to the patient and others (Fig 6-24). The best solution to very large apical base midpoint discrepancies is, of course, orthognathic surgery to place the jaws on center.

The Posterior Midpoint

The third factor to consider in establishing a treatment midpoint is the mesiodistal location of the posterior teeth. If, in one's judgment, the right and left posterior teeth of each arch are correct in their relative anteroposterior positions, then the center or midpoint of the arch circumference (from one molar around to the opposite molar) is the treatment midpoint. The emphasis here is on the difference in positions of the right and left buccal segments within each arch. This difference is based on the axial inclinations of the posterior

Fig 6-25 The posterior midpoint is the geometric center of the arch circumference. Starting from the desired position of the first molars (red line), equal radii are marked off on the right and left sides (blue lines). Where the right and left radii cross anteriorly, the posterior midpoint is located.



teeth and is independent of whether one desires to move the buccal segments forward or backward.

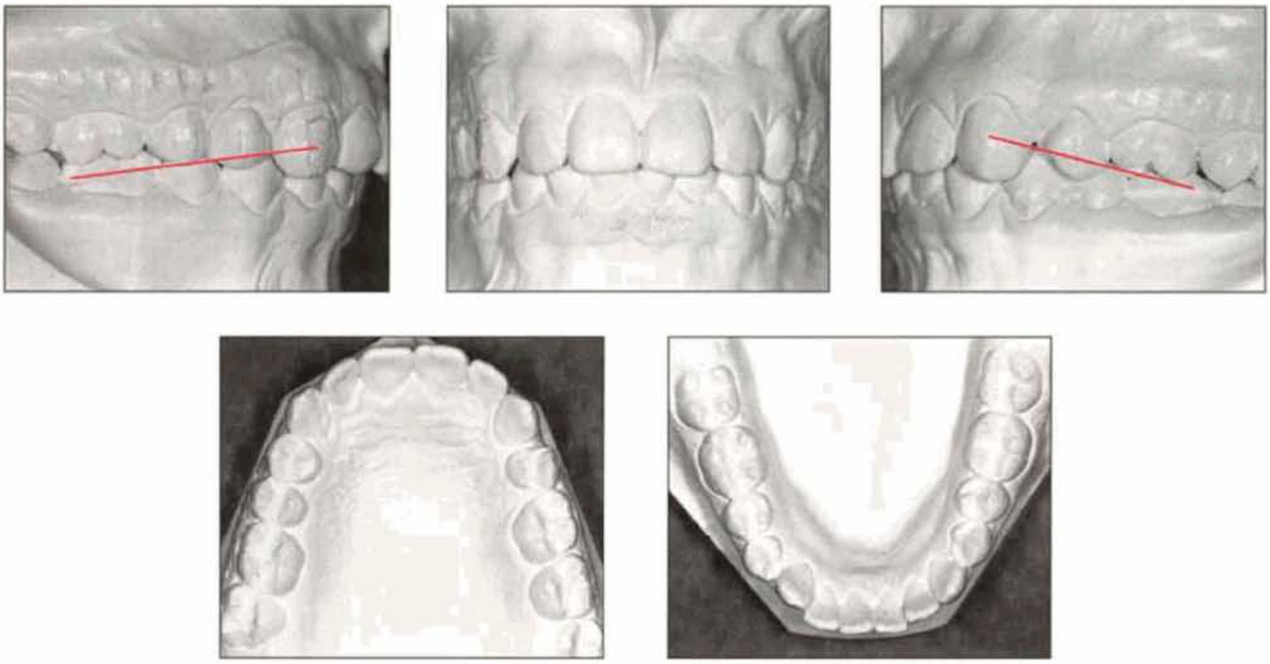
Figure 6-25 shows the arcs (made with dividers) that are used to establish the posterior midpoint. Starting from the mesial of the first molar on each side, the posterior midpoint is found where bilaterally symmetrical radii cross at the center of the arch. A perpendicular bisection of a line connecting the right and left first molars might not locate the posterior midpoint at the same point since both the arch width and the arch form can be different from right to left. There might also be anteroposterior differences in the posterior segments from right to left that require measuring along the arch circumference.

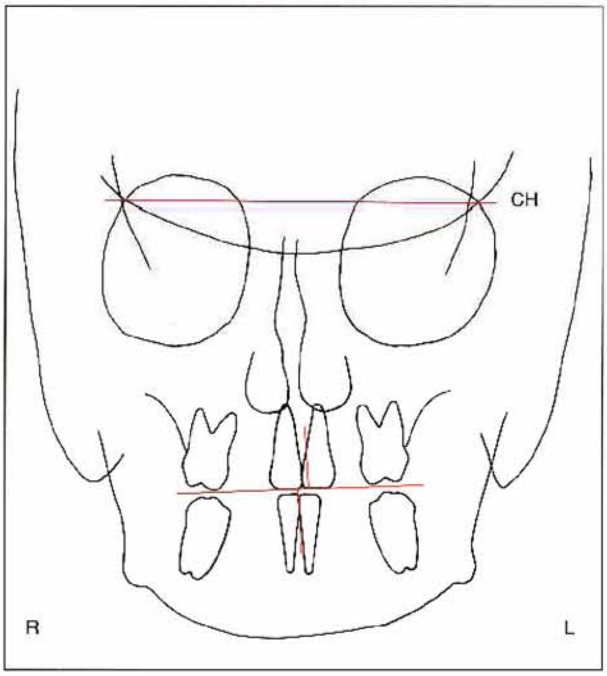
If the molars are unilaterally tipped, a correction is made before marking off the radii with dividers. For example, buccal segments that have asymmetrical axial inclinations are mentally uprighted to produce symmetrical axial inclinations. The tipped teeth are mentally (or on a separate tracing) rotated around a point near the centers of their roots, and an estimate is made of how many millimeters the mesial of the first molar moves mesially or distally. The same result could be accomplished by tipping either the normal or the abnormal side so that the axial inclinations are symmetrical.

Normalization of axial inclinations to allow a more accurate posterior midpoint is a clinical judgment based in part on the unilateral mechanics that will be used; therefore, normalization may be less or more than simply rotating around root centers. Using the posterior midpoint as a treatment midpoint requires no significant asymmetrical mechanics in the buccal segments.

Fig 6-26 Patient KP. Early loss of an upper left second premolar. a, Study casts, before treatment. Note the tipped first molar on the left side. b, Tracing of posteroanterior headfilm, before treatment. Note apical base midpoint relationship. c, In the upper arch, the posterior midpoint is to the right of the facial and apical base midpoints (red, facial midpoint; blue, apical base midpoint; green, posterior midpoint). The patient can be treated by moving the left buccal segment distally to align the posterior midpoint or by treating the left side to a Class II molar occlusion and the right side to a Class I molar occlusion. d, Lateral headfilm tracing showing the rotation of the upper first molar about the center of its root.

a





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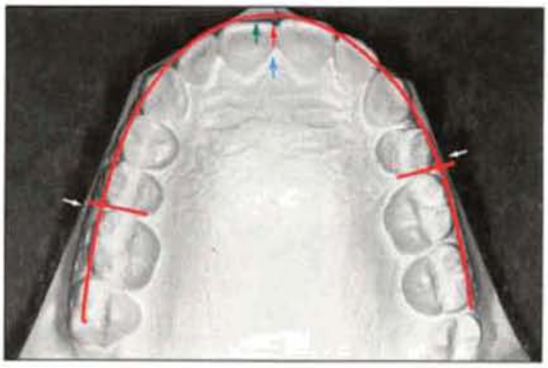

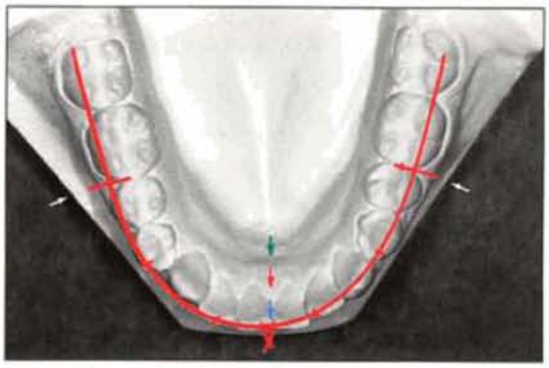

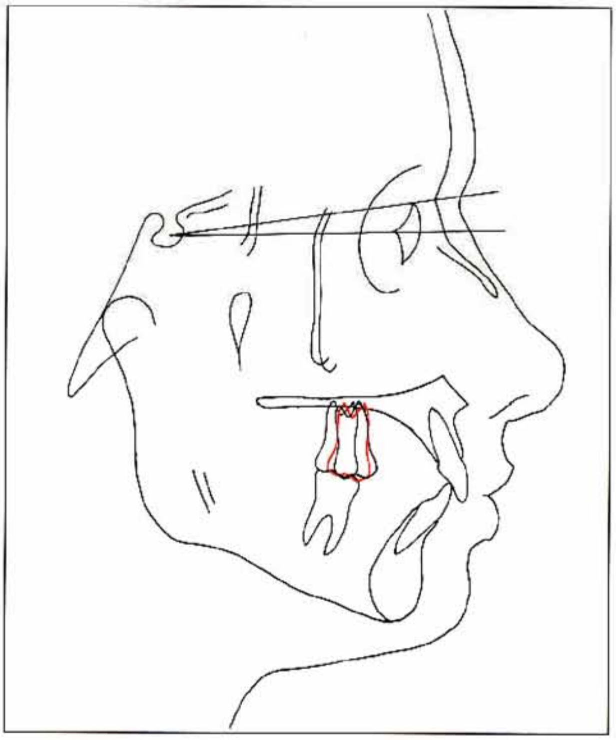

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Patient KP had a Class II malocclusion associated with early extraction of the upper left second premolar (Fig 6-26a). If the molars are to remain in their initial positions, the posterior midpoint is to the right of both the incisor midpoints and the apical base midpoints (Figs 6-26b and 6-26c). There are two ways to align the posterior, facial, and apical points. The first is to accept the missing premolar and treat to a Class II molar occlusion on the left side, maintaining the incisor midpoint position. The second is to consider distal movement of the left molars. Tipping around the center of the left molar root will distalize the molar. If this can be achieved, the posterior mid-

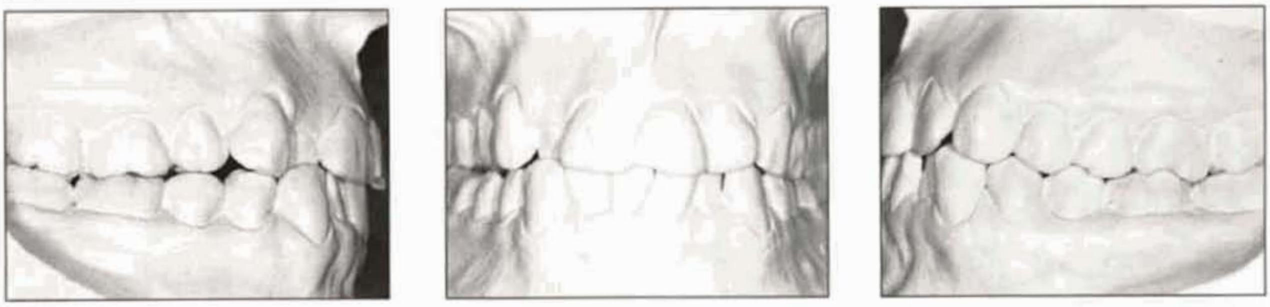
Fig 6-27 Patient SC. Missing upper right first premolar. Class II occlusion on the right and Class I occlusion on the left. Asymmetrical mechanics were used. a, Frontal facial photographs, before and after treatment. b, Study casts, before treatment. c, The occlusogram superposition shows the asymmetrical molar movement in the upper arch (left side moved forward). Red arrow, facial midpoint; blue arrow, apical base midpoint; green arrow, posterior midpoint. d, Study casts, after treatment. The upper left and lower right and left first premolars have been extracted. e, Tracing of the posteroanterior headfilm, before treatment. f, Tracing of the posteroanterior headfilm, after treatment. Lower incisors were tipped to the right because of the apical base discrepancy. g, Lateral headfilm tracing, before and after treatment, showing tooth movement.

a

point will be moved to the left, but not enough to correspond to the other midpoints (Fig 6-26d). With better mechanics, the molar could perhaps be moved further distally, but the presence of an erupted second molar compounds the problem. The patient was treated to a Class II molar occlusion on the left side. Since the left second premolar was not present, no bridge or implant was required. If this patient had not been missing a tooth and had been treated at a younger age, a preferable treatment would be to move the left first molar distally so that the posterior midpoint would be coincident with the facial and apical base midpoints.

Patient SC had an asymmetric posterior occlusion that showed a more pronounced Class II on the right (Figs 6-27a and 6-27b). The upper and lower apical base midpoints did not coincide, the lower being to the left of the upper (Fig 6-27e). The upper incisor midpoint was coincident with the upper apical base midpoint and the lower incisor midpoint was to the left of the lower apical base midpoint, showing considerable tipping to the left of the lower incisors. The upper right first premolar had been extracted, resulting in mesial drifting. From the occlusal view, good symmetry was found in the lower arch (Fig 6-27c). In the upper arch, the posterior midpoint was far to

b



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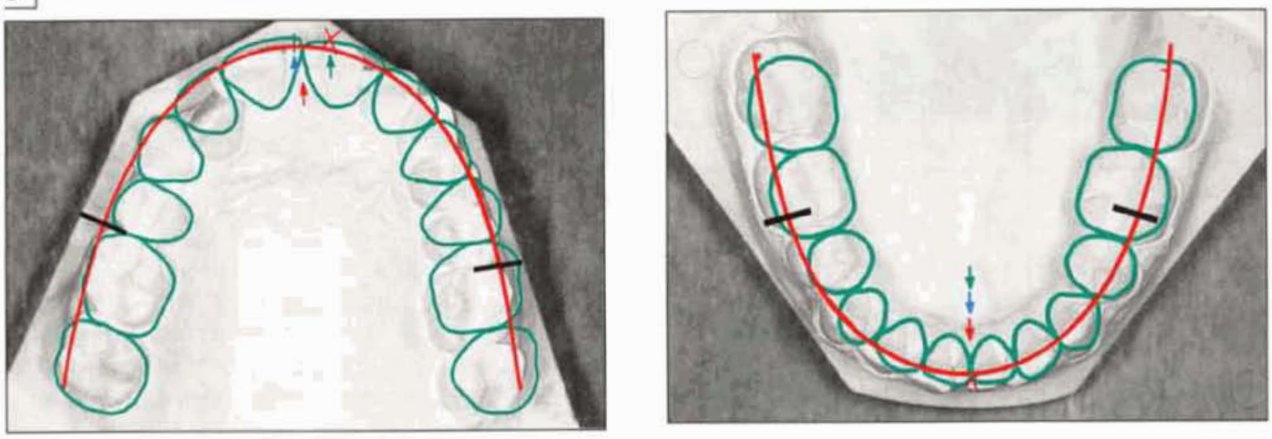

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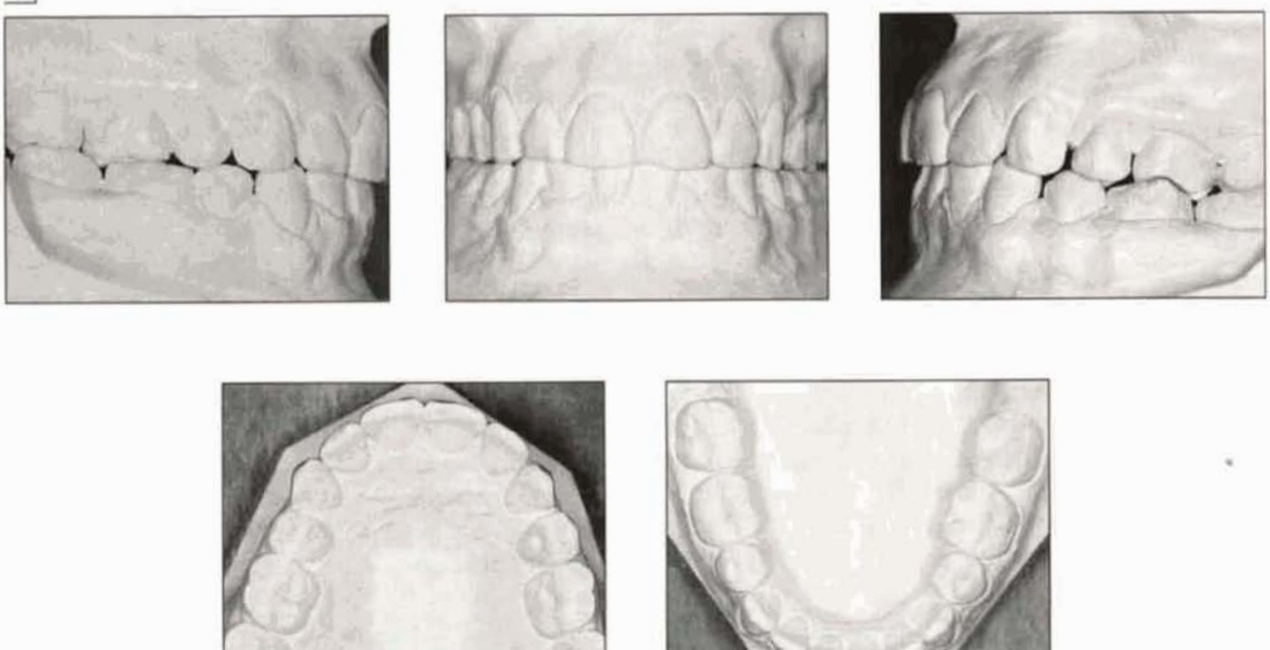

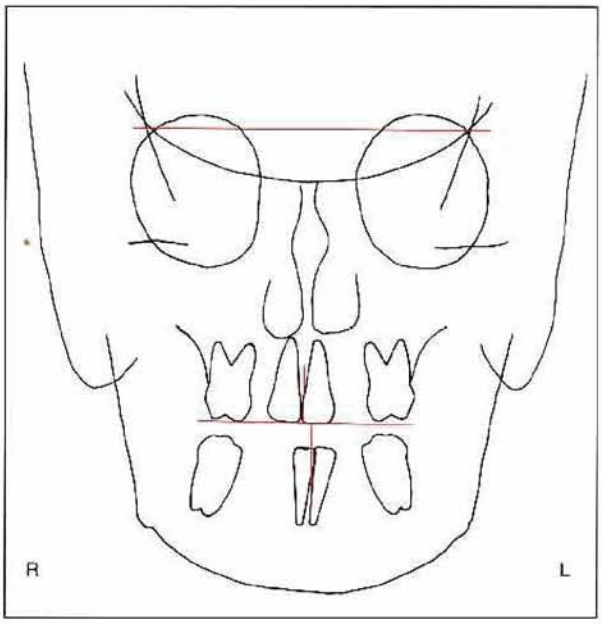

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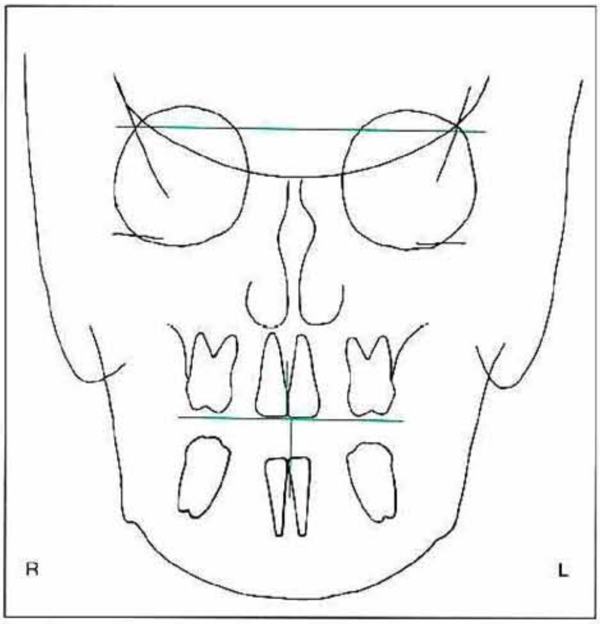

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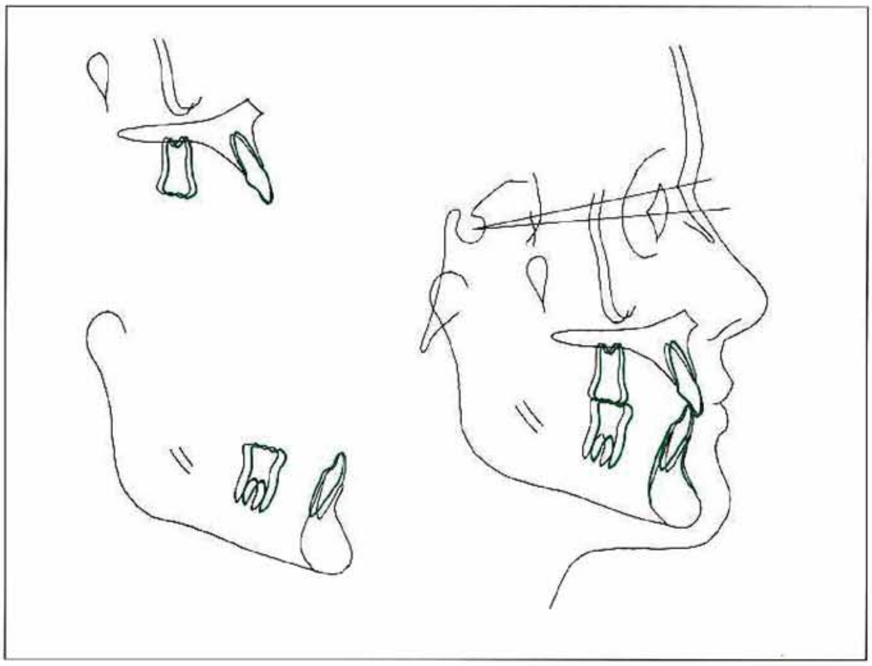


g

— original position — treatment objective — treatment outcome

Fig 6-28 Patient LC. Posterior and apical base midpoints were in alignment. Treating to these midpoints maintained an incisor midpoint to the right of the facial midpoint landmarks. With this patient it would be unreasonable to treat to the facial midpoint since posterior movement of both upper and lower buccal segments on the left side is required.

the left of the upper incisor midpoint, the facial midpoint, and the apical base midpoint. The upper left first premolar and both of the lower first premolars were extracted. The treatment midpoint was selected so as to be in line with the upper apical base midpoint. To bring the posterior midpoint in line with this objective, asymmetrical mechanics were used in the upper arch to bring the left buccal segment forward (Fig 6-27c). Incisor midline correspondence was achieved by tipping the lower incisors to the right slightly beyond the lower apical base midpoint (Fig 6-27f).

When symmetrical Class I occlusion presents itself, it is difficult not to treat to the posterior midpoints since upper and lower midpoints are aligned. But what if the facial and posterior midpoints are different? Patient LC presented this dilemma. Treatment to the posterior midpoint placed the incisor midpoint to the right of subnasale and cupid's bow (Fig 6-28). Treating to a facial midpoint with arch harmony would require moving both upper and lower buccal segments posterior on the left side, which might be considered unreasonable. Part of the problem is associated with the asymmetrical bulbous nose displacing subnasale to the right.

Selecting the Treatment Incisor Midpoint

Selecting the point on the arch where the incisors are to be placed is not a trivial decision. Arbitrary geometric constructs can lead to undesirable occlusal correction and poor esthetics. Five clinically relevant points on the dental arches are used to establish the treatment midpoint: the facial midpoint, the upper and lower apical base midpoints, and the upper and lower posterior midpoints. In patients whose midpoints are not coincident, one can either make them coincident by means of orthognathic surgery or choose a compromise treatment midpoint. To determine a reasonable treatment midpoint, one must consider the relevance of the various midpoints. For example, the facial midpoint is important for esthetics but its determination is rather imprecise; hence, it is not surprising that a variation of up to 2 mm often goes unnoticed by the patient. More weight is placed on the apical base midpoint. If incisors have to be translated laterally, every millimeter of tooth movement is mechanically very difficult. As was noted earlier, a discrepancy of 3 mm or more in the apical base midpoint relationship is often cause to recommend an orthognathic surgical procedure since lateral

translation is limited. The tipping of incisors to correct an apical base midpoint discrepancy may not be esthetic. The upper apical base midpoint is given more weight since lateral tipping of the lower incisor is not so apparent. The posterior midpoint receives much weight because asymmetrical movement and mechanics are clinically challenging.

A posterior and apical base midpoint discrepancy is correlated in a true skeletal asymmetry. For instance, if the mandible (pogonion) is off center, the posterior teeth will differ on the right and the left. There are some apical base midpoint discrepancies that are purely dental in origin. An example is a patient with a missing upper lateral incisor whose central incisors have drifted into the space without any obvious tipping. This type of discrepancy is nevertheless genuine, requiring consideration when choosing a treatment midpoint.

The mesiodistal width of the teeth also influences the treatment midpoint. The treatment midpoint is useful for the overall planning of a patient's orthodontic treatment; hence, symmetry is assumed. In the detailed planning, however, the primary goal is good symmetrical posterior intercuspation, while upper and lower midpoint correspondence is of secondary importance. Some patients with large lower incisors, for example, can be treated with the extraction of a single lower incisor. The lack of upper and lower midpoint correspondence is inconsequential provided there is good posterior intercuspation.

A word is warranted about the potential confusion between points, lines, and planes. Our goal has been to select a treatment incisor midpoint for each arch. A line perpendicular to the treatment occlusal plane and passing through this incisor midpoint represents the treatment incisor midline. From the occlusal view, a line parallel to the midsagittal raphe through the incisor midpoint (other lines may be clinically more relevant) also forms a treatment midline. With these points, a treatment incisor plane is established.

7

Chapter

Management of Arch-Length Discrepancies

Discrepancies between arch length and mesiodistal tooth diameters are relatively common. While it is not uncommon to measure an arch-length inadequacy or redundancy using the original arch form, it is more meaningful to delay the arch-length measurement until the arch form and treatment midline have been established. As a treatment goal, upper and lower arch forms—representing points on the incisal edges or the tips of the buccal cusps of the teeth—have already been drawn. These are the outer arches. It now becomes necessary to draw the inner arch forms, which represent the means of the contact areas of the finished case, since the arch length would be measured along these contact areas. The inner arch lies lingual to the outer arch by an amount that is dependent on the desired axial inclination of the teeth and the distance between the tips of the buccal cusps–incisal edges and the contact areas (Fig 7-1).

There can be more variation in the labiolingual axial inclination of the lower incisors than in the inclination of any other tooth in a treatment plan. Figure 7-2 shows that, as incisor flaring increases, the perpendicular projection from the lower incisor contact area to the occlusal plane lies further to the lingual of the incisal edge. If a lingual axial inclination of the incisors is anticipated—as in some Class III skeletal discrepancies—the contact area could actually lie to the labial of the incisal edge.

From the lateral treatment plan tracing of the incisor axial inclinations (Y-Z plane), the distance from the inner and outer arches can be measured. Actually, the study casts give the best indication of the distance between the tips of the cusps and the contact areas. The distance between posterior cusp tip and the mean of the mesial and distal contact area is measured for each tooth (Fig 7-3). The difference between incisal edges or buccal cusp tips and the contact areas can now be recorded on the occlusogram. Accuracy in establishing the inner arch is very important in properly determining an arch-length discrepancy.

After the inner and outer arches have been drawn, the mesiodistal diameters of the teeth can be marked so as to represent the exact arch-length status (Fig 7-4). The treatment midpoint is transferred from the outer arch to the inner (contact area) arch by extending it parallel to the midsagittal plane. Using dividers or vernier calipers, the mesiodistal diameter of each tooth—from the central incisors to the second premolars—is measured on the dental cast and marked on the inner arch starting at the treatment midpoint. Each distal surface is marked with a short buccolingual line. The distal surface of the second premolar is indicated with a slightly longer buccolingual line.

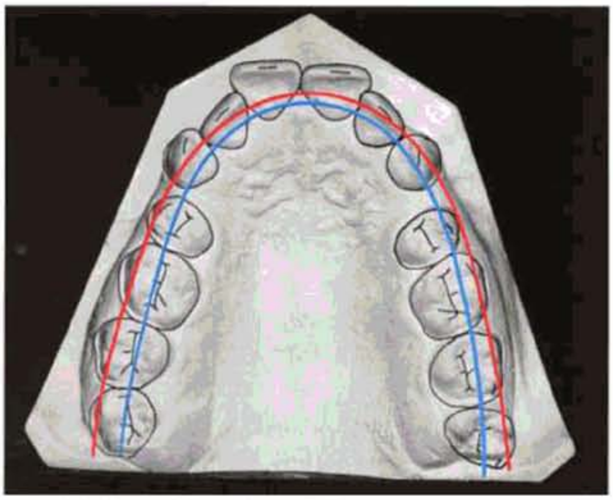


Fig 7-1 Two different arch forms are drawn on the occlusogram. The outer (red) arch extends through the buccal cusp tips and the incisal edges, whereas the inner (blue) arch extends through the contact areas of the planned tooth positions.

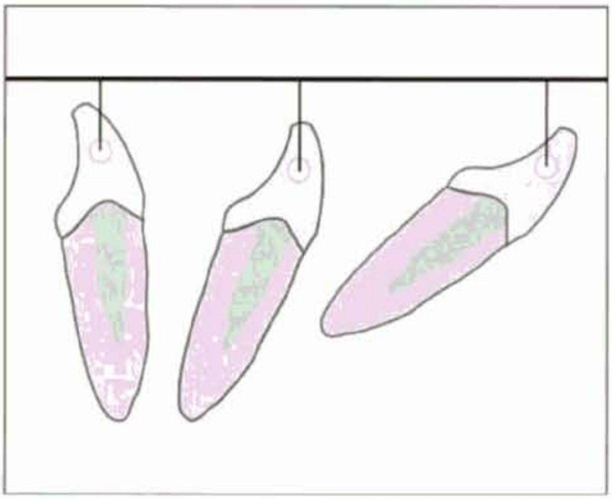


Fig 7-2 The distance between the outer and inner arches varies according to the axial inclination of a tooth. The more it is flared, the further lingual is the contact area of a lower incisor.

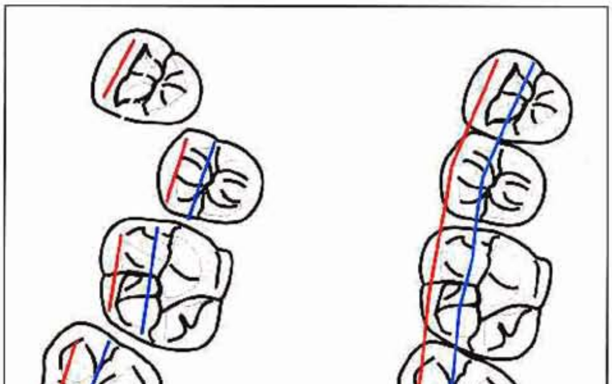


Fig 7-3 The distance between the posterior cusp tips (red) and the contact area (blue) is measured for each tooth (a) and averaged (b) to establish the inner arch.

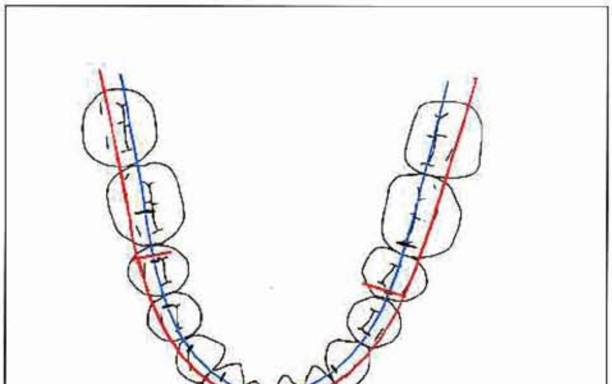


Fig 7-4 The mesiodistal diameters measured on the study casts are marked along the inner arch with short buccolingual lines (black). The arch inadequacy is the distance between the original molar (black) and the black buccolingual line of the second premolar. Since extractions are planned (the lower right first and lower left second premolars), the longer red buccolingual line is the resulting position of the mesial of the first molar. Note that the arch-length inadequacy and planned molar movement differ from right to left.

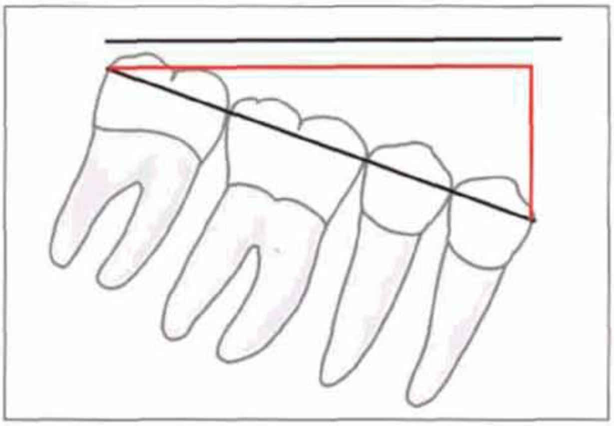


Fig 7-5 Projected mesiodistal diameters to the occlusal plane produce an error in measuring tooth size if the teeth are tipped. The actual size (black) is larger than the projected size (red); more space in the arch is needed to accommodate the teeth.

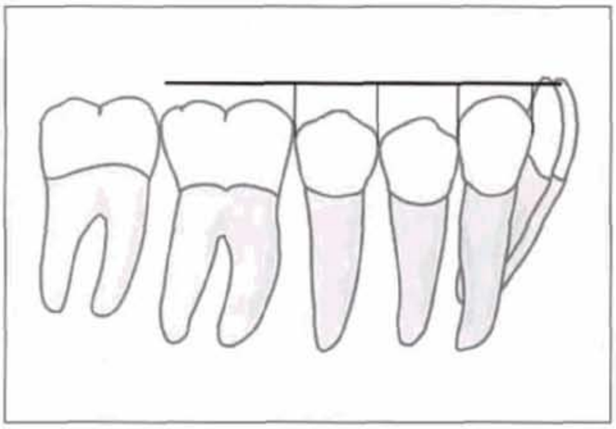


Fig 7-6 If a curve of Spee is combined with normal axial inclinations, no additional space is needed in the arch since only vertical tooth movement is required.

The distance between this line and the mesial of the first molar is the arch-length discrepancy—that is, an inadequacy or redundancy. If the distal of the second premolar is 5.0 mm distal of the mesial of the first molar, then the arch-length inadequacy for this quadrant is –5.0 mm; if the distal of the second premolar is 3.0 mm mesial to the mesial surface of the first molar, then an arch-length redundancy of +3.0 mm exists.

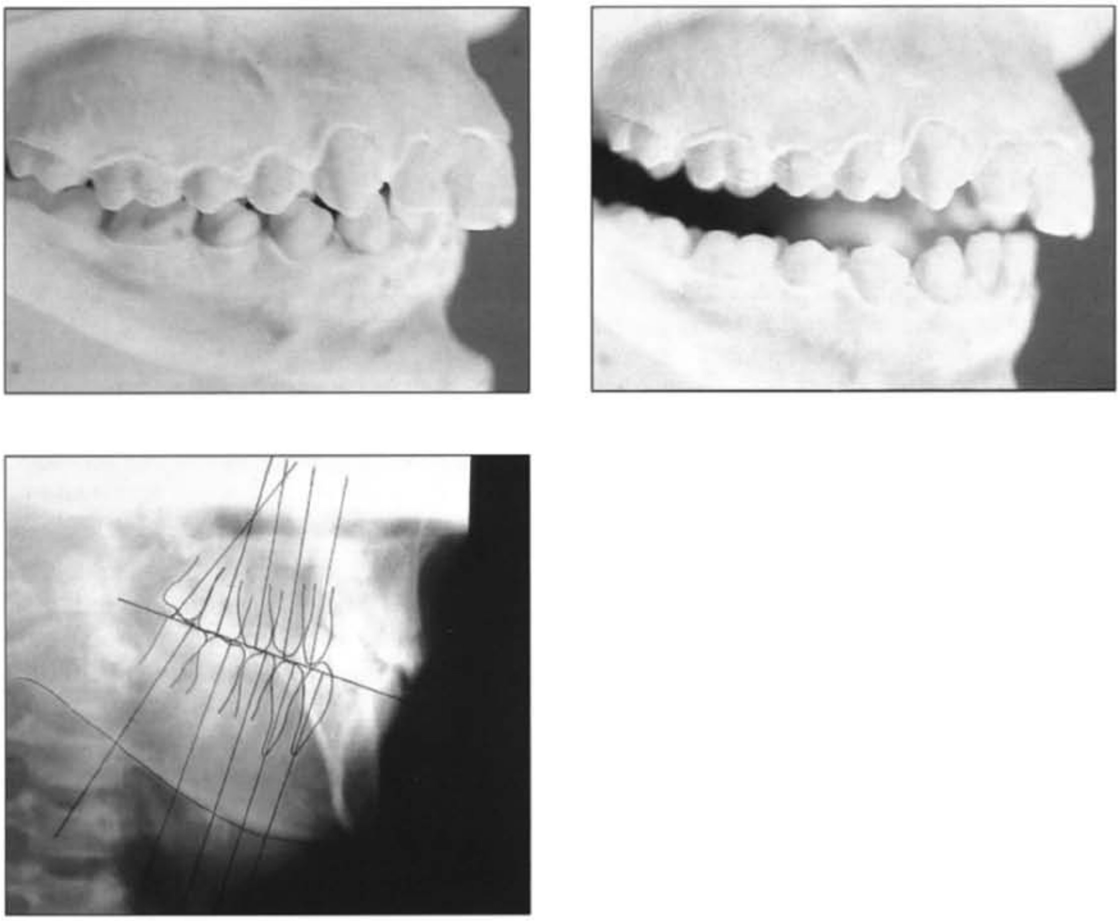
Orthodontists will often describe an arch-length inadequacy as a measurement for the entire arch. This can be misleading because the inadequacy can vary from one quadrant to another. Let us say a patient has a total arch-length inadequacy of 7.0 mm; this could mean a symmetrical inadequacy of 3.5 mm per side or, as in Fig 7-4, an asymmetrical inadequacy of 2.0 mm and 5.0 mm on the lower left and lower right sides, respectively.

Determining the arch-length discrepancy based on the original arch form is unnecessary and misleading since the treatment goal may alter not only the arch widths but also the anteroposterior position of the incisors. During the mixed dentition stage, the measurement of the initial arch length and an estimation of tooth size are used to predict future arch-length inadequacies. The problem with simplistic mixed dentition analyses is that future changes in arch dimension are not considered and it is assumed that the leeway space can be used for mesial molar movement. As implant studies have shown, there is much mesiodistal variation in the movement of both incisors and molars if leeway space is present. Any planning in the mixed dentition stage should be based on the treatment goal arch width and arch form rather than on the original arch form.

It is often said that if a curve of Spee is present in the lower arch, more space is needed for tooth alignment. This may or may not be correct, depending on how an arch-length discrepancy is measured. With the procedure described in this book, arch length is measured on a perpendicular projection of the arch on the occlusal plane (occlusogram), and tooth size is an actual measurement made from the dental casts. Therefore, no added compensation is required to account for a curve of Spee.

If dividers are not used and the mesiodistal tooth diameters are taken from the occlusogram itself, the projected widths will be smaller than the actual widths when the teeth have tipped mesiodistal angulations (Fig 7-5). When a curve of Spee is combined with normal axial inclinations, measuring tooth size as a perpendicular projection to the occlusal plane does not require additional tooth width compensation (Fig 7-6). Lower premolars and canines can be moved vertically to

Fig 7-7 Deep overbite with an excessive lower curve of Spee. a, Teeth in occlusion. b, Dental casts separated to show the curve of Spee. c, Lateral and 45-degree headfilms show normal axial inclinations. No additional space is needed in the lower arch to correct the curve of Spee.



level the plane without any increase in arch length. There are two types of curves of Spee: one with mesially inclined posterior teeth requiring more space and another with normal posterior axial inclinations requiring no additional space. The second type of curve of Spee is the more common in nonextraction cases. Figure 7-7 shows a malocclusion with a deep overbite. From both the study casts and the radiographs, it is apparent that the anterior and posterior teeth have normal axial inclinations requiring only vertical movement, and no increase in arch length is necessary.

A commonly used method for measuring arch length is to place a brass wire on the occlusal surfaces of the teeth from the first molar to the incisors. However, when a curve of Spee is combined with normal axial inclinations, a false reading results from this method. As it is straightened out, the curved brass wire becomes longer, suggesting that more arch length is required than

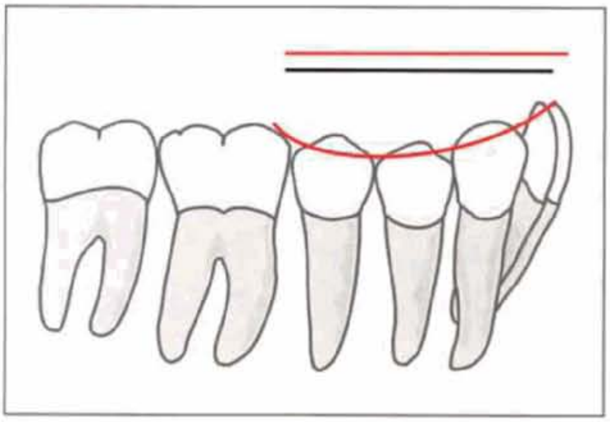


Fig 7-8 Measuring arch length with a brass wire leads to error if the wire is curved to fit a curve of Spee. Black, correct length; red, straightened brass wire.

actually exists (Fig 7-8). One advantage of the occlusogram technique is that the actual tooth sizes are measured from the dental casts; once those measurements are transferred to the planned arch form, no other calculations are needed with respect to a curve of Spee.

Arch-Length Inadequacies

The most common arch-length problem is an arch-length inadequacy. A shortage of space leads to symptoms such as crowding, malalignment, and rotations. The problem can be generalized or specific to a region. Crowding is usually seen in the incisor, canine, or premolar segment, but it can also be a problem in the molar region, where it is sometimes overlooked if arch length is measured from the mesials of the first molar. Radiographs should be used to evaluate the room available for erupting second and third molars. Nonextraction treatment that involves moving the posterior teeth distally can shift the arch-length inadequacy from the anterior region to the molar region of the arch.

Another manifestation of an arch-length inadequacy is protrusion of the incisors. In these patients, teeth may be in good alignment or somewhat spaced; however, an inherent inadequacy is present since arch length is based on a treatment goal that includes retraction of the incisors. Other symptoms of a shortage of space include delayed eruption, dental midpoint noncorrespondence, and vertical alignment irregularities.

There can be many causes of arch-length inadequacy. Teeth can be too large or the arch length can be too small. A small arch length can be associated with a jaw that is small either in the anteroposterior or in the transverse dimension. One of the more common causes is a narrow basal arch in the canine and premolar region. Conversely, skeletal or basal arch width may be adequate, but incisor retrusion or narrow canine widths (seen when the canines are leaning lingually) may nonetheless result in inadequate arch length. Most narrow dental arches, however, are the result of a skeletal width deficiency.

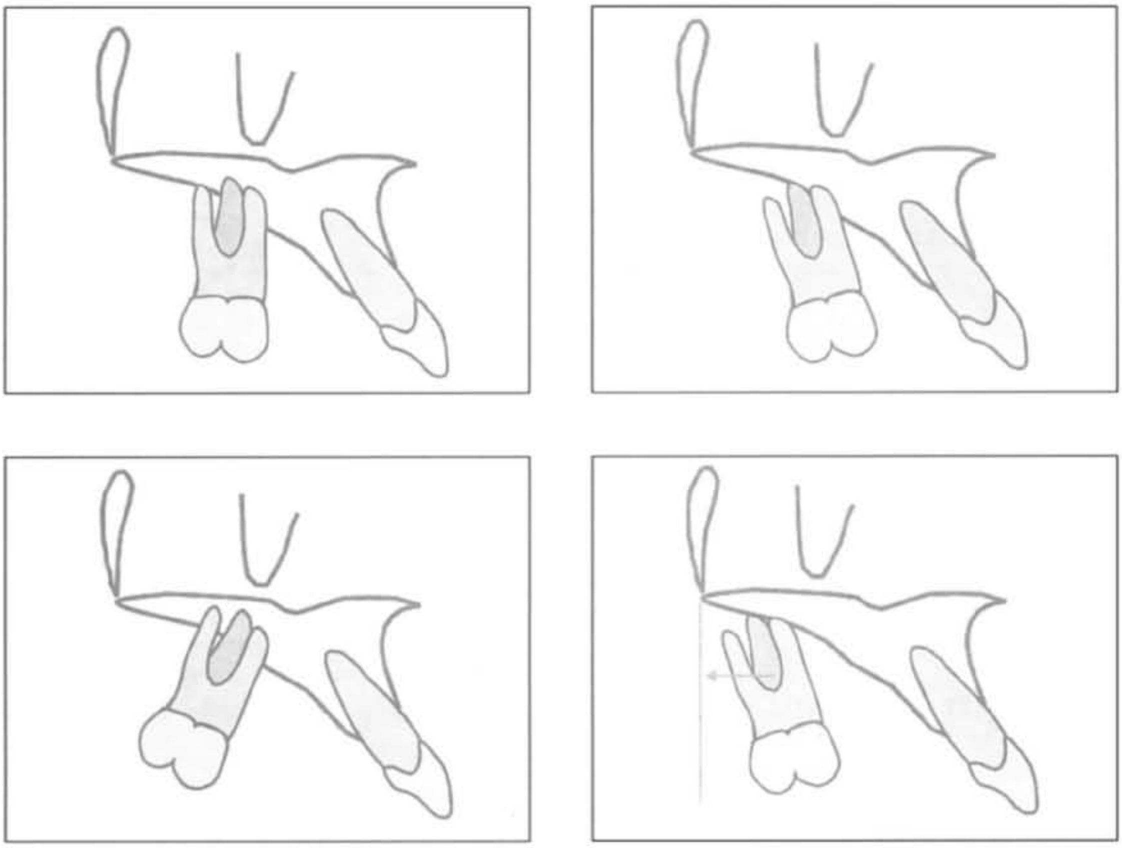
Distal movement of posterior teeth

The first solution that must always be considered in arch-length inadequacies is the possibility of moving posterior teeth distally. At this stage of treatment planning the arch width and the anteroposterior position of the incisors have already been established; therefore, unless the treatment plan is revised, the only option is to consider the possibility of moving the molars distally. The indications for distal movement of the molars require an evaluation of three major factors: molar axial inclinations, available posterior space, and growth.

In a normally developing dentition with typical molar axial inclinations, distal movement of the

Fig 7-9 Molar axial inclination is a factor in its successful distal movement. a, Normal axial inclination requires distal translation. b, Molar tipped mesially is favorable. c, Molar tipped distally is unfavorable because it requires both distal translation and distal root movement. d, Molar tipped mesially is desirable, but inadequate space posteriorly makes it undesirable for distal movement.

a b c d



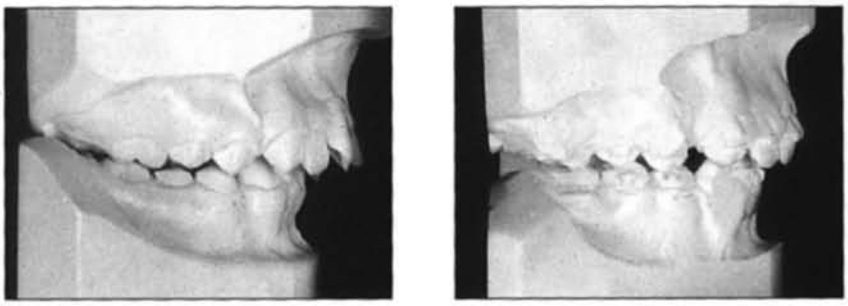
molars would require that they be translated distally (Fig 7-9a). Unfortunately, this might encroach upon the space needed for the eruption of the second and third molars. Figure 7-9b shows a more favorable situation; that is, the upper molar is tipped mesially. Simpler mechanics are needed for distal tipping than for translation, and there is more room posteriorly. Distal molar movement is contraindicated in Fig 7-9c, where the molar is already distally inclined. Both distal root movement and translation would be required, which would be biomechanically challenging, and there is a lack of sufficient space posteriorly. The molar in Fig 7-9d has a favorable axial inclination for distal tipping; however, insufficient space exists posteriorly.

The patient in Fig 7-10 was treated with a cervical headgear to tip the upper posterior teeth distally (Figs 7-10a and 7-10b). Headgear therapy might have been successful if mandibular growth had occurred while the upper arch was held; however, no growth was observed in this early-maturing female. At the beginning of treatment, insufficient space was available for the erupting second and third molars. Note that after treatment the second and third molars are severely impacted and the distal tipping is undesirable. Had distal translation of the molars been attempted, even more severe root contact and impaction of the molars would have occurred. This patient demonstrates two contraindications for moving upper molars distally: lack of space posteriorly and unfavorable axial inclinations.

Future growth is an important factor to consider before planning distal molar movement. In the maxilla, tuberosity growth can add to the available space; furthermore, mandibular growth typically moves the upper teeth downward and for-

Fig 7-10 Headgear therapy was used to move the upper molars distally. Undesirable axial inclinations and a lack of posterior space contraindicated distal molar movement. Note the impaction of the second and third molars. a, Study casts, before and after treatment. b, Lateral headfilms, before and after treatment.

a



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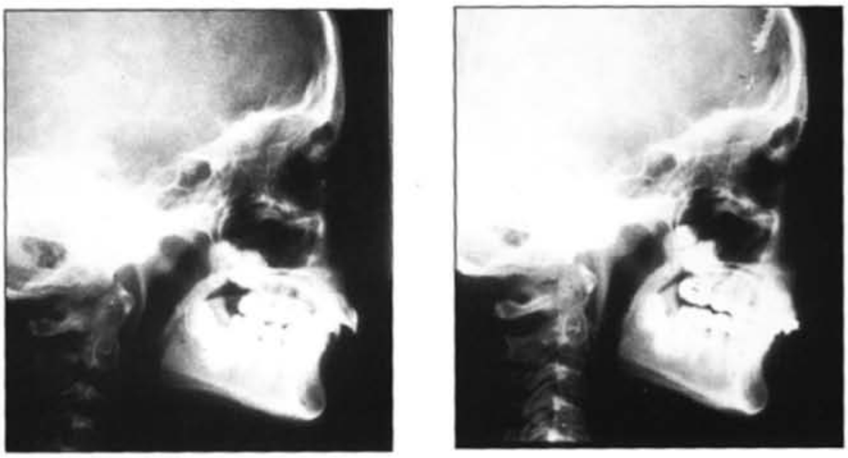


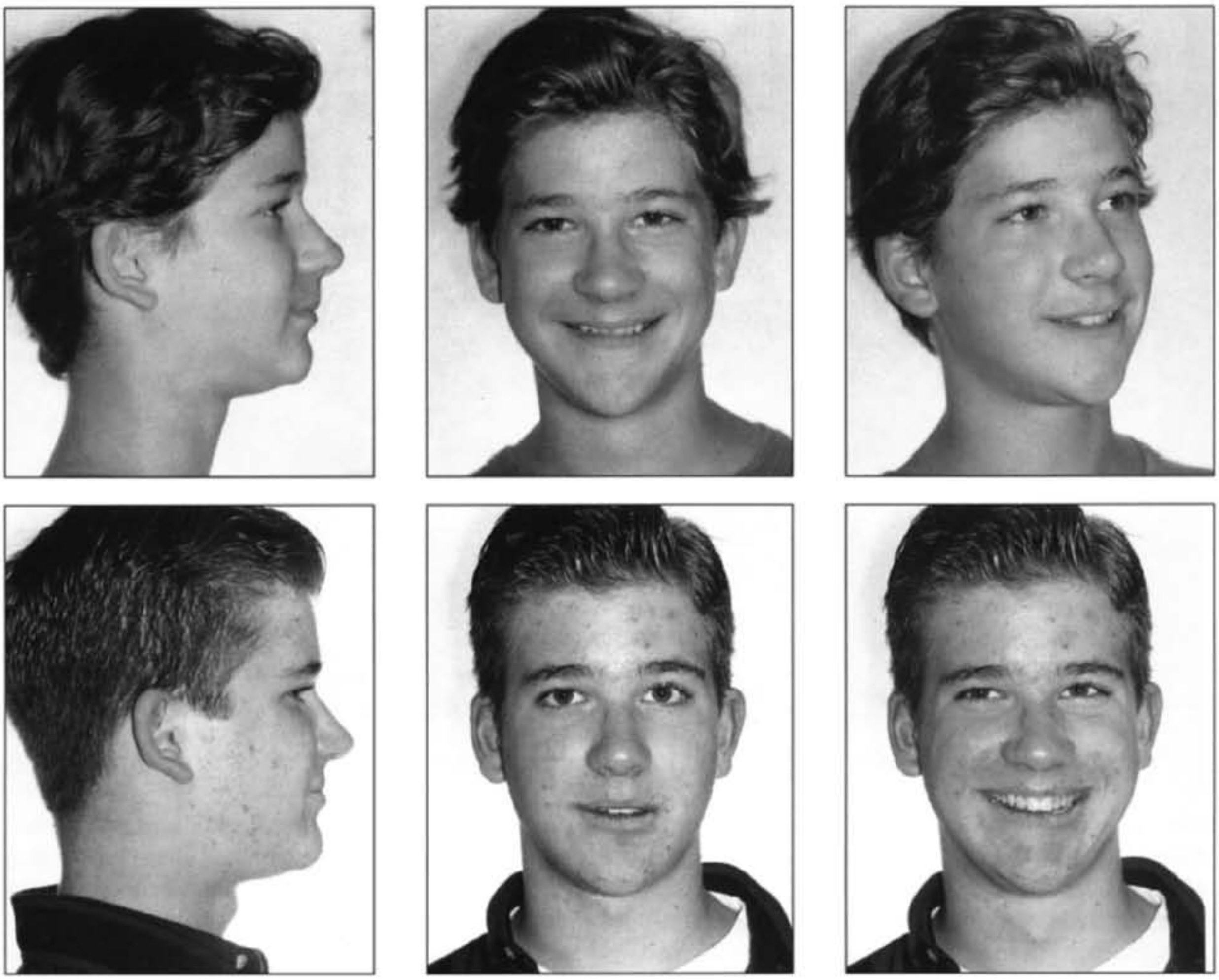
ward, allowing more space for the erupting upper second and third molars. Mandibular growth increases the space in the retromolar region. Most successfully treated Class II patients rely primarily on differential mandibular growth achieved through restraint of the upper posterior teeth rather than actual distal movement of these teeth.

When upper first molars need to be moved distally and insufficient space exists, space can sometimes be made by removing the upper second or third molars. If the third molars are removed before distal movement commences, molar distal movement is facilitated. In younger patients, surgical intervention with third molars still in their crypts can be problematic; even waiting could be uncertain since impacted teeth may also be difficult to extract. Although some orthodontists may extract second molars to gain room for distal movement of the first molar and to facilitate tooth movement, usually no more than 2 to 3 mm of the second molar space is used for distal movement of the first molar. The most successful Class II second molar extraction cases are achieved through differential maxillomandibular growth rather than actual distal molar movement. Removal of the upper second or third molars in a Class II patient can really be considered extraction therapy. If successful, obviously there is no problem; however, if the premolars must be removed later in treatment, good third molars would have been better maintained. The effect of removing upper second molars can be unpredictable since correction of the Class II is dependent on patient compliance and favorable growth, neither of which is guaranteed.

The complexity of the mechanics heavily influences the decision to move the posterior teeth distally. Moving the posterior teeth distally in one

Fig 7-11 Patient BB. No distal movement of the upper arch was required. Differential maxillomandibular growth corrected the Class II occlusion. a, Facial photos, before and after treatment. b, Study casts, before and after treatment. c, Lateral headfilm tracings, before and after treatment. d, Occlusogram treatment-plan tracing. The short black lines represent the arch length required relative to the first molar; the short red lines represent the desired treatment position of the first molar. e, Occlusogram tracings, before and after treatment.

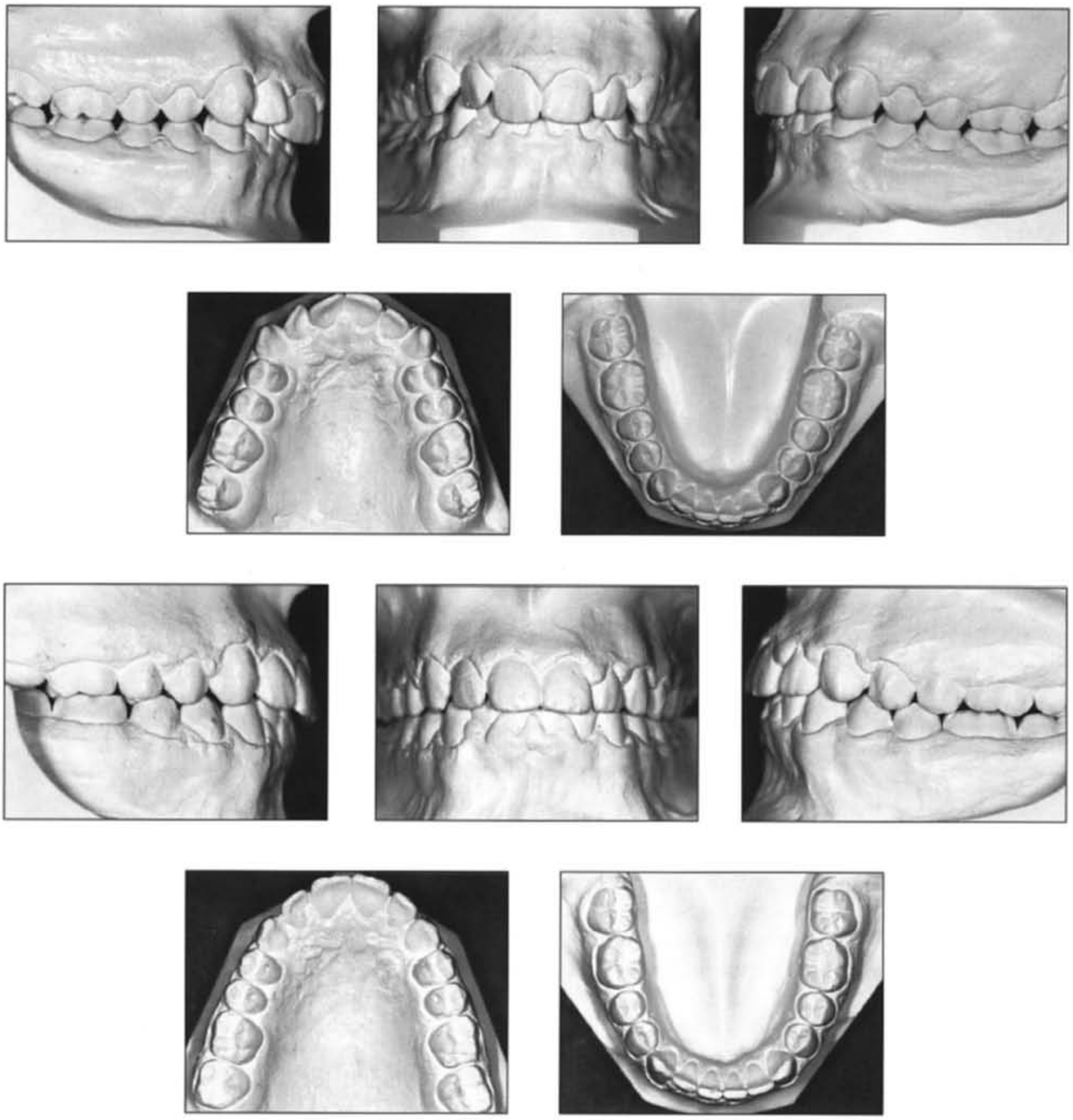
a



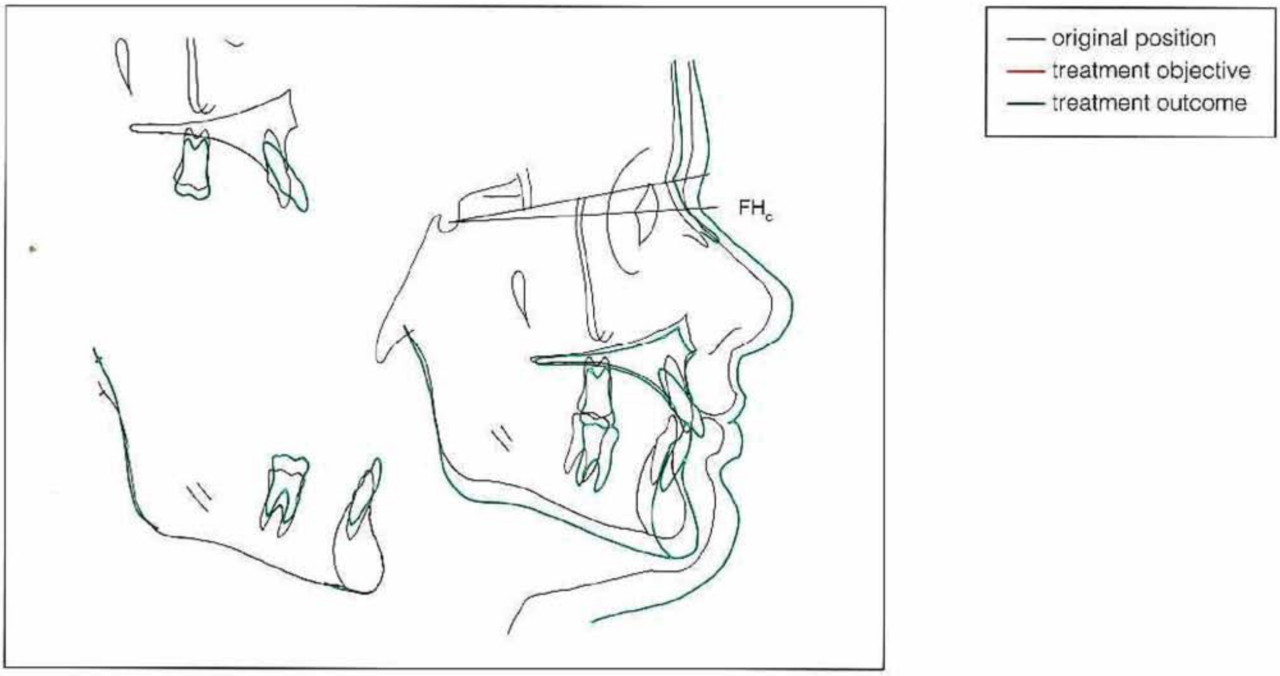
arch is significantly easier than moving them distally in both arches. Individual teeth that are tipped mesially can be tipped distally without a distal force by combining incisor intrusion and molar tip-back, for example. Distal translation is more difficult since it requires a distal force, root retraction couples, and sometimes intrusion forces.

Patient BB, a 13-year 10-month-old male, exhibited a Class II malocclusion with upper anterior crowding and a deep overbite (Fig 7-11). Figure 7-11d shows an occlusogram treatment plan for each arch without any growth considerations. With the new arch form, no arch-length inadequacy exists in either arch. However, if the treatment goal is to maintain the lower anteroposterior incisor position, the upper arch must be retracted 2 to 3 mm for proper overjet and molar occlusion. Because it was anticipated that the patient would soon undergo his pubertal growth spurt, the differential maxillomandibular growth was not expected to require upper arch retraction. The before-after lateral cephalometric and occlusogram tracings show that growth cor-

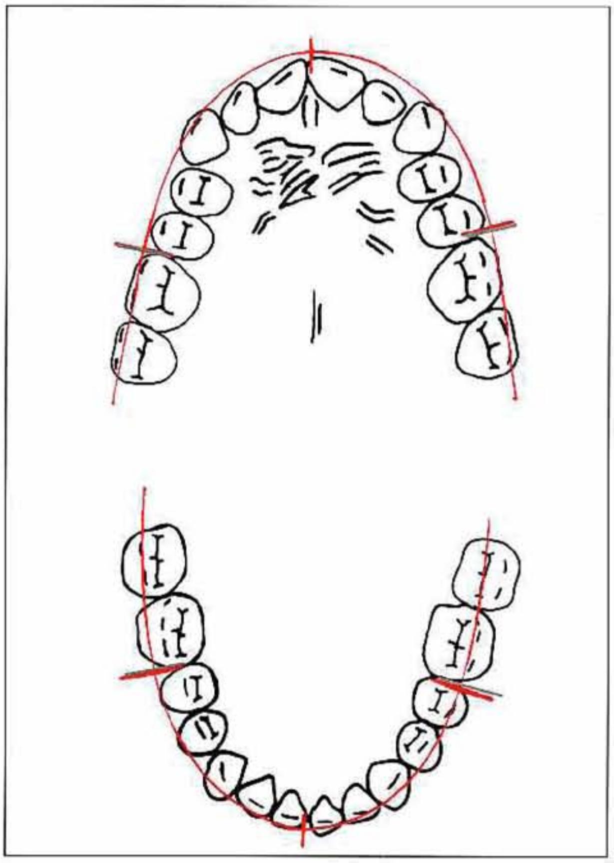
b



rected the Class II and avoided a potential upper arch-length problem. Note that at the end of treatment the upper and lower posterior teeth are in approximately the same anteroposterior position (Figs 7-11c and 7-11e). Without favorable growth, an upper arch-length inadequacy of 2 to 3 mm would have required distal movement of the upper posterior teeth. The treatment mechanics involved a simple headgear and arch alignment; instead of moving the upper posterior teeth distally, the headgear held the upper arch during the period of significant mandibular growth.


FH$_c$
original position
treatment objective
treatment outcome

c



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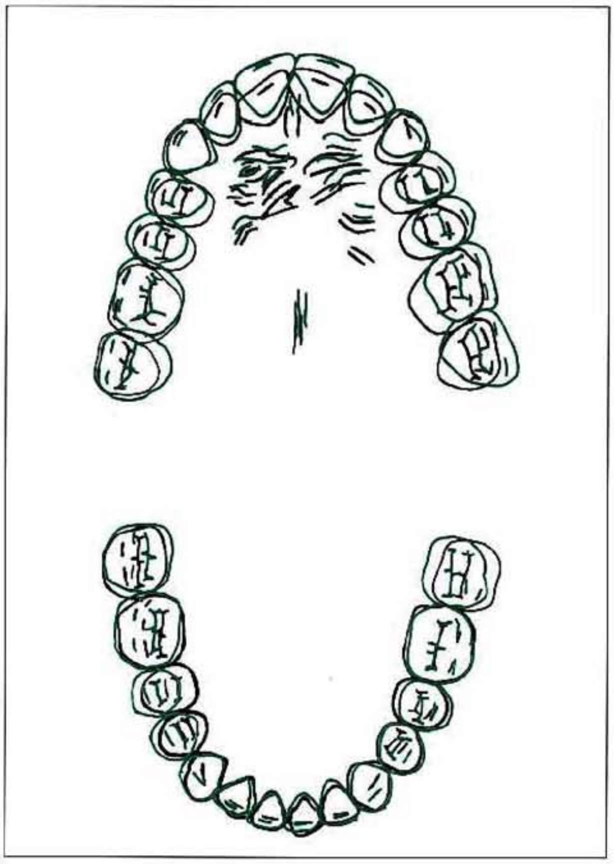

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Fig 7-12 Patient DR. Unlike patient BB, no favorable growth occurred. Significant distal movement of the upper teeth was required to correct the Class II occlusion. Growth prediction erred; the pubertal growth spurt occurred after treatment. a, Facial profile before and after treatment. b, Study casts, before and after treatment. c, Growth prediction tracing. d, Posteroanterior headfilm tracing. e, Occlusogram treatment plan using the growth prediction differential (3 mm). f, Lateral headfilm tracings, before and after treatment. g, Occlusogram tracings, before and after treatment. h, Lateral headfilms, before and after treatment. Note the difference between the distal of the upper second molar and the pterygomaxillary fissure, which has been reduced after treatment (right).

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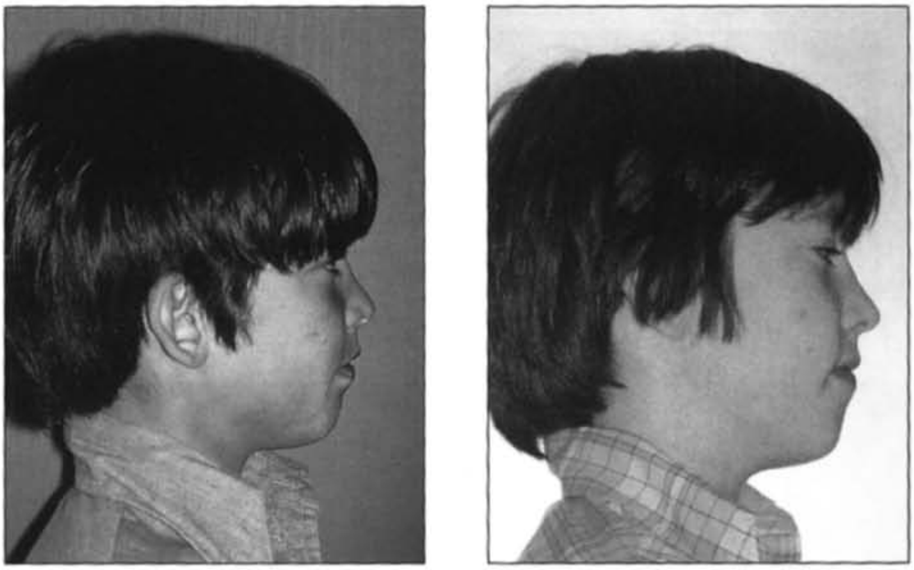
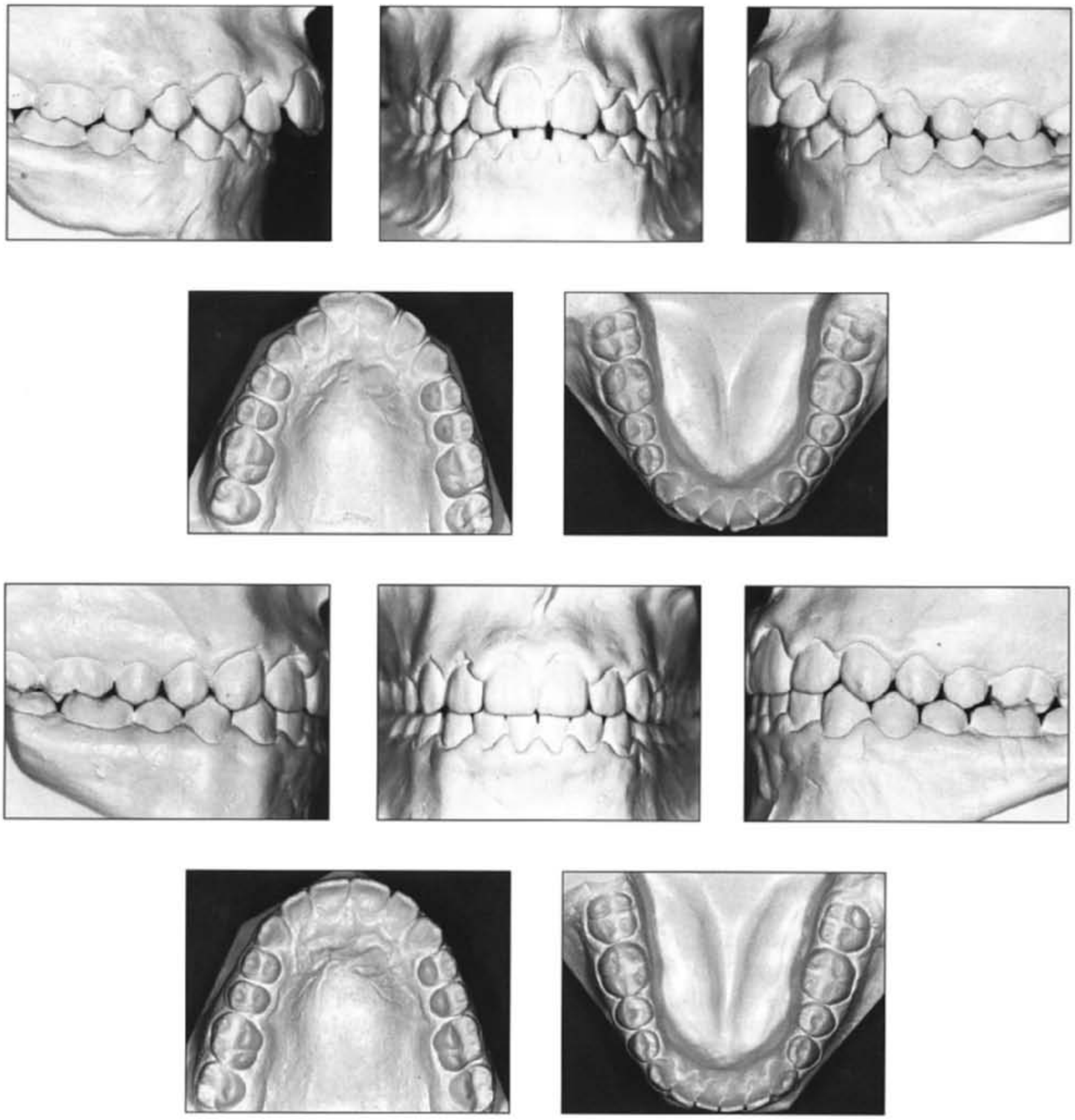
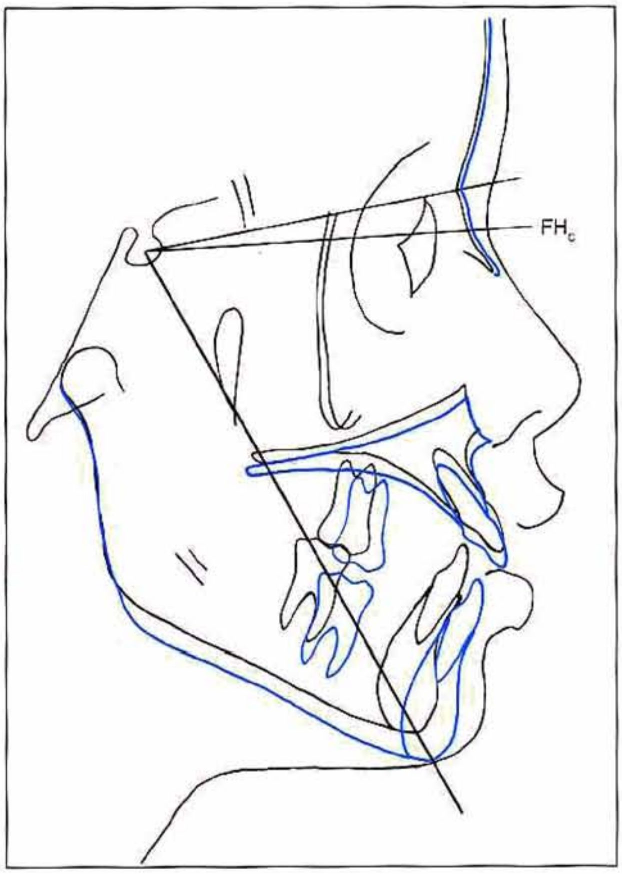


Patient DR, a 12-year 10-month-old male, presented with a Class II occlusion with no arch-length inadequacy in the lower arch (Fig 7-12). A growth prediction suggested that significant pubertal growth could improve the point A-point B relationship to the occlusal plane by 3 mm (Fig 7-12c). No apical base midline discrepancy was found on the posteroanterior headfilm (Fig 7-12d). The treatment plan occlusogram, which incorporated the 3 mm growth differential, required approximately 6 mm of incisor retraction. A decision was made to use a combination of the growth differential and approximately 4 mm of distal movement of the upper molars to correct the Class II. Unfortunately, unlike patient BB, the anticipated growth did not occur during treatment (Fig 7-12f). Treatment mechanics to the upper arch included an occipital headgear with an intrusive and distal pull. Patient headgear compliance was excellent, which resulted in distal translation of the molars (Figs 7-12f and 7-12g). The upper incisors were translated lingually relative to the maxilla. Retraction of the incisors with a nonextraction treatment significantly reduced the lip protrusion. The before- and after-treatment lateral headfilms demonstrate that, initially, space was available (from the distal of the first molar to the pterygomaxillary fissure) for distal movement of the upper molars (Fig 7-12h). Following treatment, the patient experienced his pubertal growth spurt; starting at a later time could have facilitated treatment, shortening his headgear requirement. Remaining growth helped to create more space for the erupting third molars during the retention and postretention periods.

b





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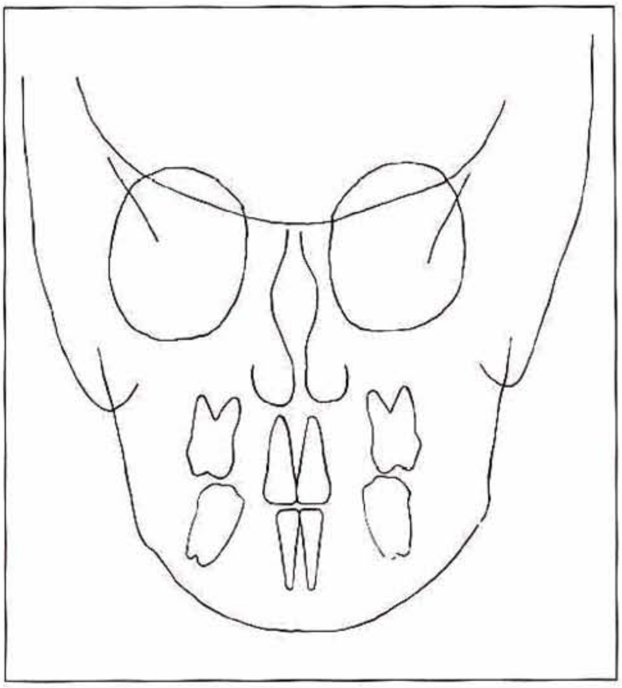
— original position — projected growth



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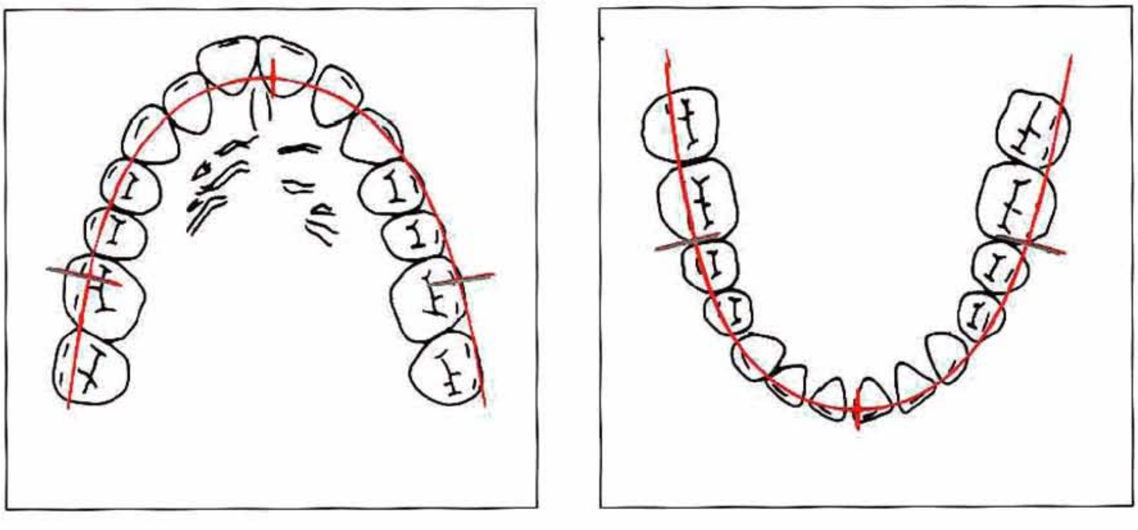

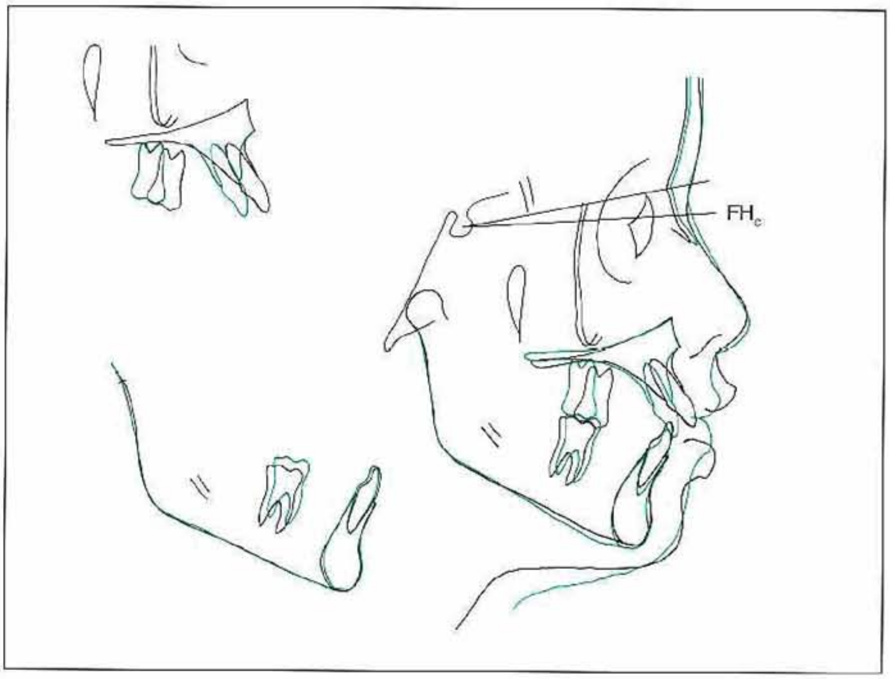

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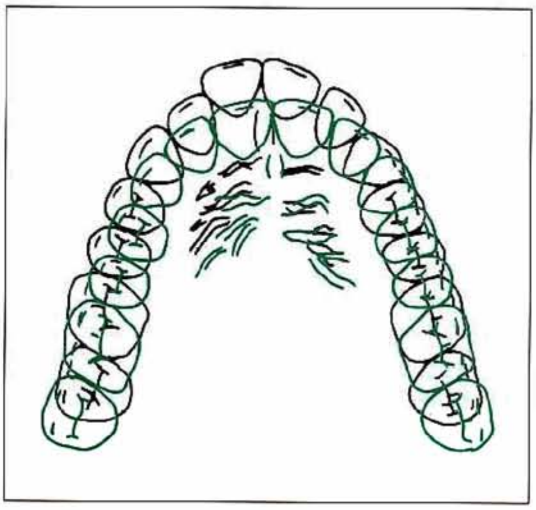
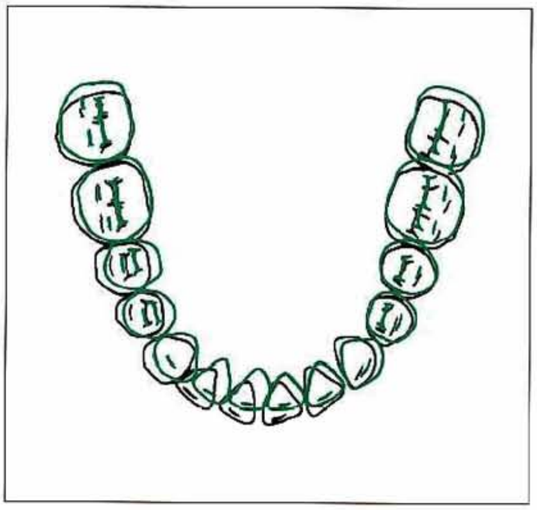
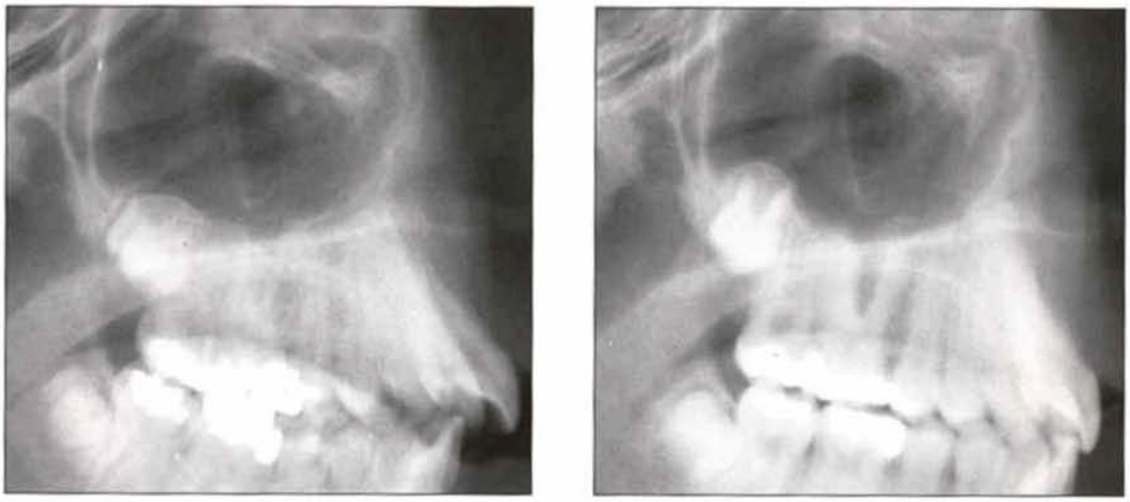




— original position — treatment outcome



h

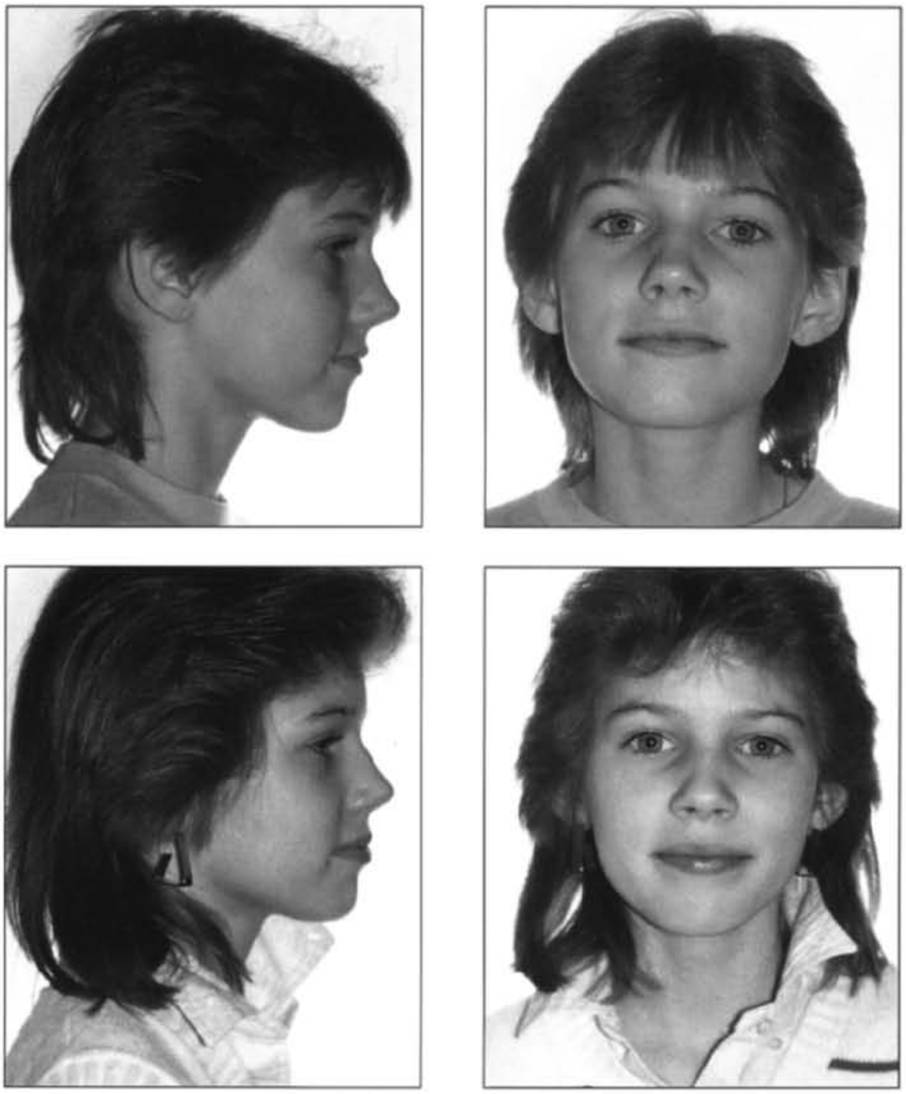
Patient CW, an 11-year 2-month old female, exhibited a slightly asymmetrical Class II occlusion, which was more pronounced on the right side than on the left (Fig 7-13). Upper and lower dental midpoints did not coincide as a result of an apical base midline discrepancy. The decision was made to use the lower dental midpoint as the treatment midpoint, which required asymmetrical mechanics in the upper arch. The growth prediction for this patient, which was reasonably accurate, suggested that about 2 mm of Class II correction could be obtained by differential maxillomandibular growth (Fig 7-13c). The treatment-plan occlusogram showed that the upper left first molar could be held in its original position while the upper right first molar was moved about 3+ mm distally (Fig 7-13d). The left first molar was tipped mesially more than the right; if it were mentally uprighted, the left side would become Class I. This is further evidence that the asymmetry in occlusion probably has a skeletal origin (Fig 7-13b). An asymmetrical headgear (combined cervical and occipital) was applied to the upper arch to retract the upper right first molar. The before-after tracings of the lateral headfilms show that the upper incisors were slightly retracted while the lower incisors were maintained in their original positions (Fig 7-13e). Both the before-after occlusograms and lateral headfilm tracings show unilateral distal translation of the right first molar (Figs 7-13e and 7-13f).

Apparent distal movement of the posterior teeth—as shown by patients BB, DR, and CW—can be real, or it can result from preventing the upper molars from advancing while allowing favorable mandibular growth to bring the lower molars forward; both procedures result in a Class II correction. Unilateral correction by distal molar movement is more challenging, and distal tipping is much easier than distal translation of the molar.

Most of the successfully treated nonextraction Class II patients do not show significant distal movement of the upper posterior teeth; rather, they rely mainly on the differential maxillomandibular growth realized with the use of either a headgear or a functional appliance.

Fig 7-13 Patient CW. Unilateral distal movement of an upper molar using an asymmetrical headgear (combination cervical and occipital with the long bow on the right side). a, Facial photos, before and after treatment. b, Study casts, before and after treatment. c, Growth prediction. d, Treatment-plan occlusogram. e, Lateral headfilm tracings, before and after treatment. f, Occlusogram tracings, before and after treatment. Results come close to the planned growth and tooth movement.

a



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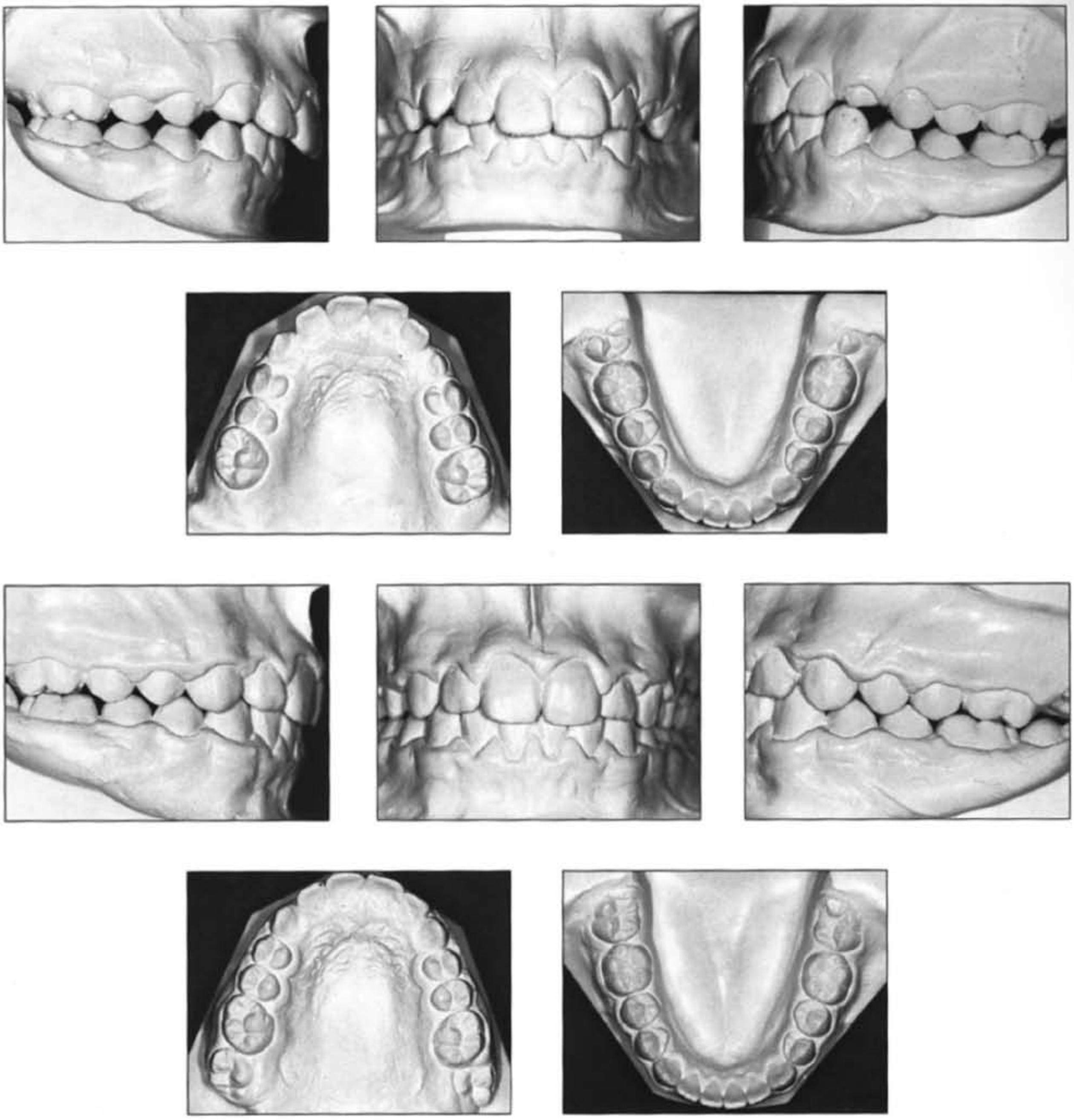

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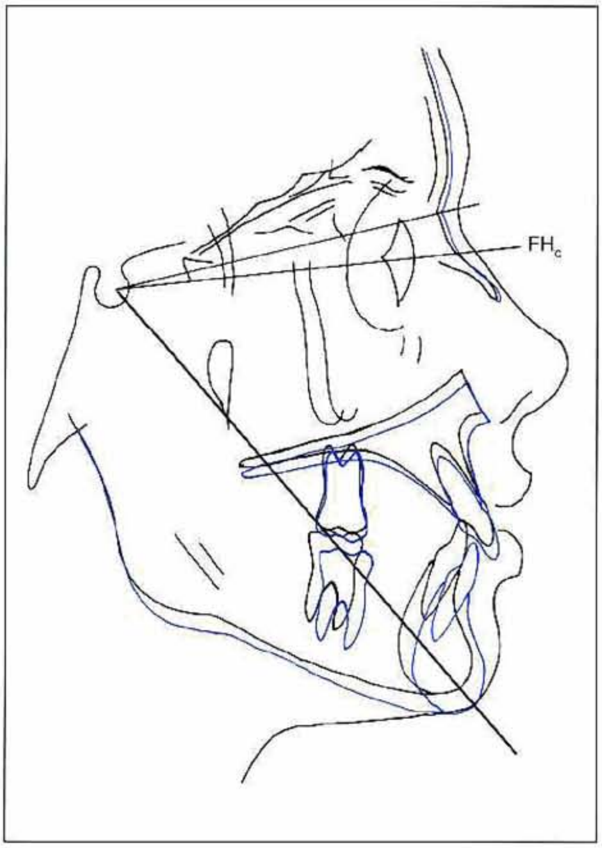

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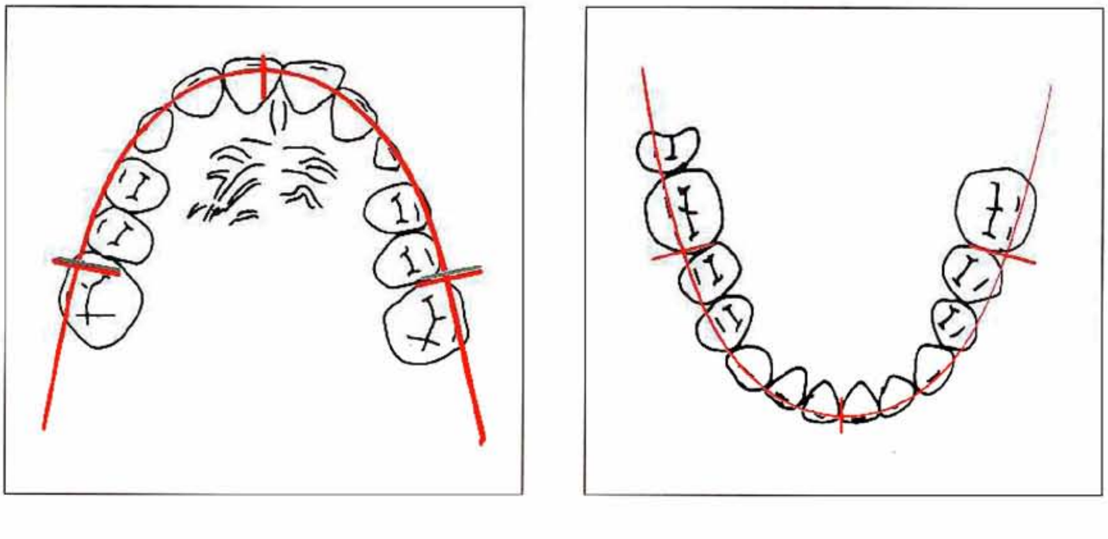

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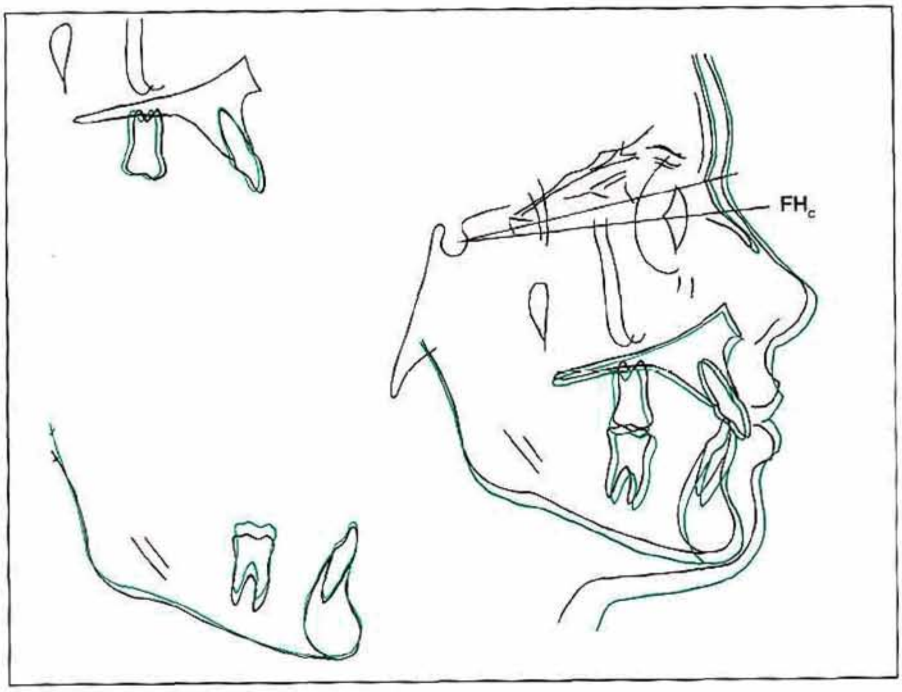
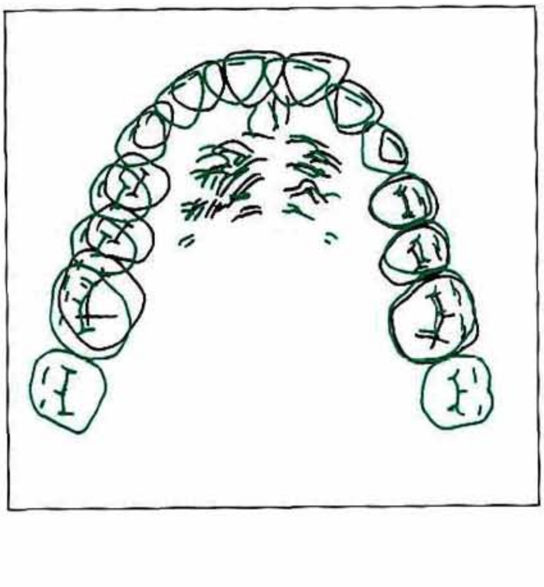


— original position — projected growth — treatment outcome

f



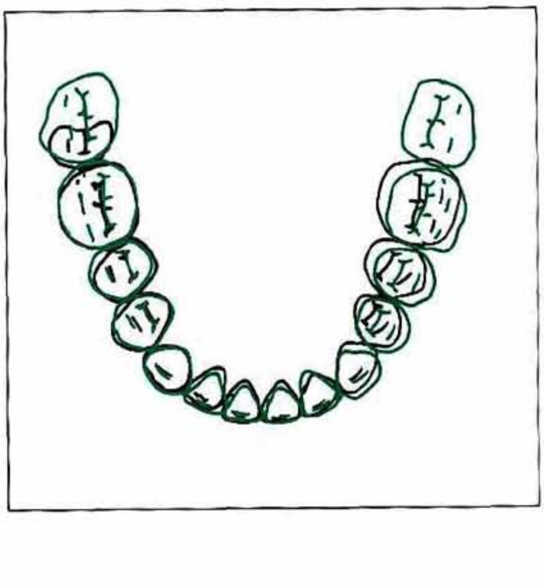
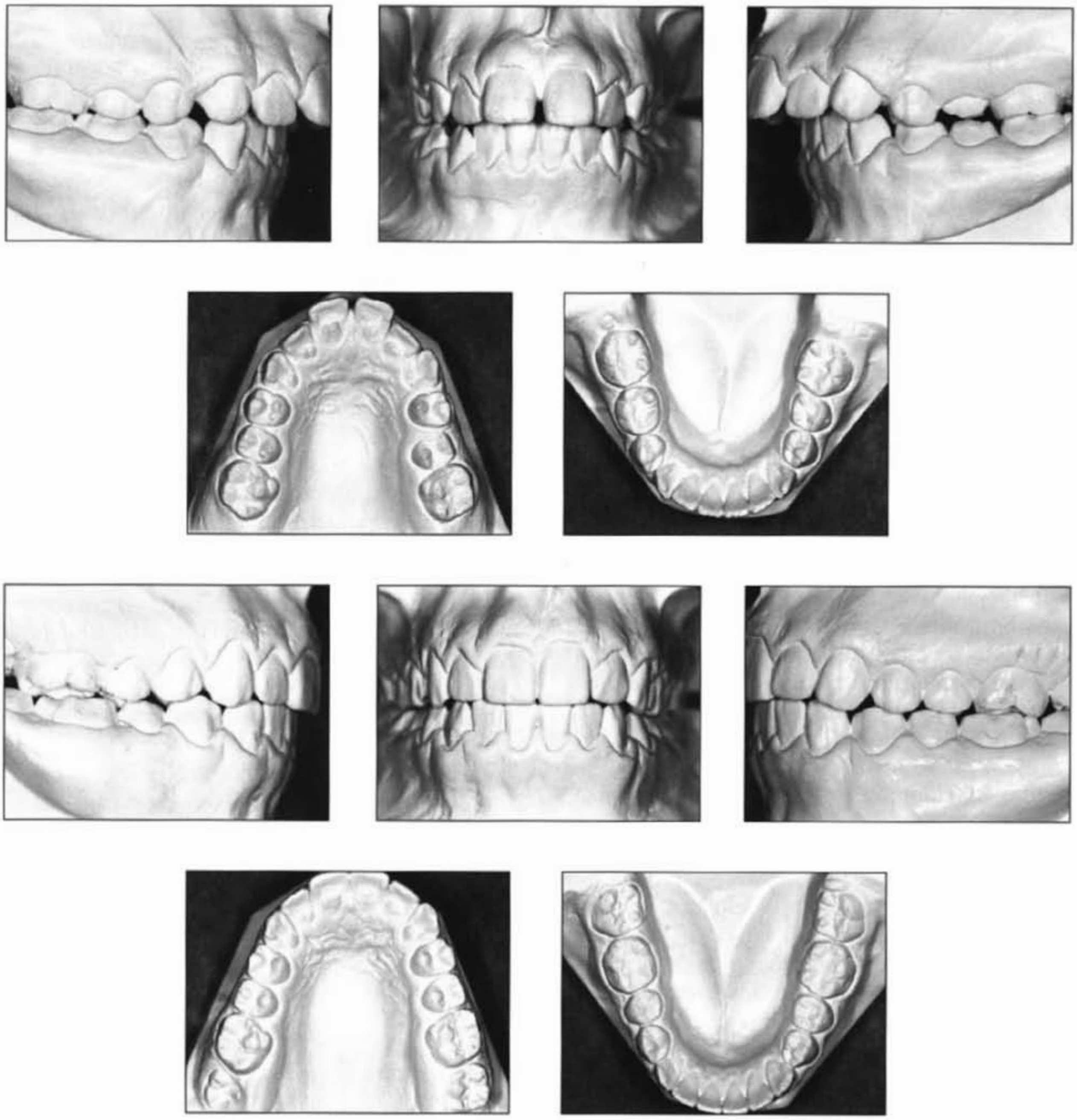


Fig 7-14 Patient MM. Mandibular rotation and initial mesial shift of the mandible made Class II correction more difficult. Fortunately, mandibular growth was large enough to correct the Class II occlusion. a, Facial photos, before and after treatment. b, Study casts, before and after treatment. c, Lateral headfilm tracings, before and after treatment. d, Occlusogram tracings, before and after treatment.

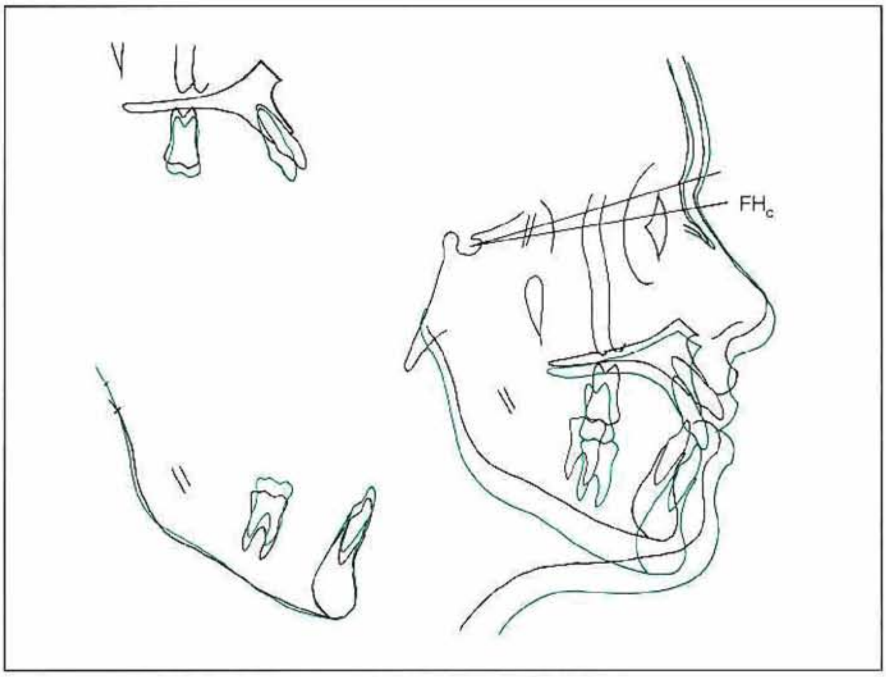
a

Patient MM, a 10-year 6-month-old female, shows a full-cusp Class II occlusion on the right side and a 3-mm Class II occlusion on the left side (Fig 7-14). A headgear with upward and backward pull through the center of resistance was applied to the upper arch. The patient experienced her pubertal growth spurt during treatment. The upper molars were not retracted but essentially held in place. Although point A came backward slightly (remodeling, normal growth, or orthopedics), most of the occlusal correction was produced by forward mandibular growth (Figs 7-14c and 7-14d). It is sometimes thought that headgear primarily affects the maxilla, but in reality it is mandibular growth that makes these cases successful. The mandibular rotation seen at the end

b



of treatment is only partially related to the tooth eruption associated with the treatment mechanics; a mesial mandibular shift, present on both the initial headfilm and the dental casts, caused the chin to move forward minimally even though a large amount of growth was recorded on the mandibular superposition (Fig 7-14c). From a final headfilm, taken 2 years after debanding, superposition shows that the mandible continued to grow and the mandibular plane flattened somewhat.



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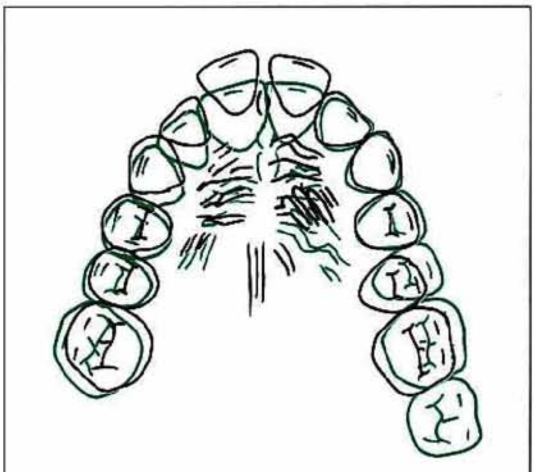

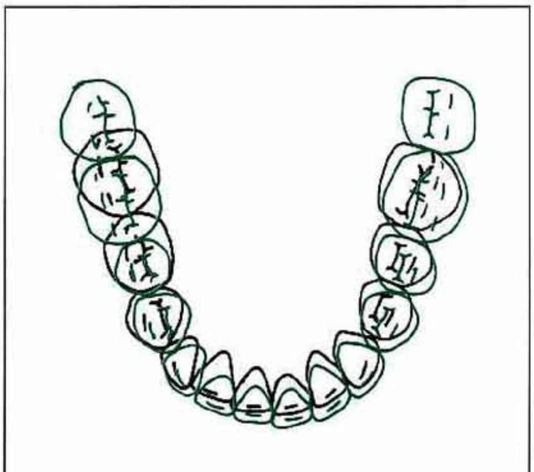

— original position — treatment outcome

Extraction therapy

It is not always possible or desirable to move teeth distally to solve an arch-length inadequacy. Sometimes removal of tooth material, usually by extraction, becomes necessary. Typically, the teeth extracted are first or second premolars; however, depending on the patient's overall goal, almost any tooth may be extracted.

The further forward in the arch a tooth is before it is extracted, the better the anteroposterior anchorage control of the posterior segments. Commonly, first premolars are extracted when posterior teeth must be maintained or can be slipped forward slightly, whereas second premolars are extracted when significant protraction of the posterior teeth is required. The same principle applies in the vertical dimension: it is more desirable to remove first premolars if incisor intrusion is needed; then the anchorage unit consists of three posterior teeth (second premolar and first and second molars), whereas only two posterior teeth (first and second molars) are available if the second premolar is removed. It has been claimed that extraction of the second premolars or first molars can aid in the reduction of the vertical dimension in open bite patients; there is little evidence to support this claim.

Other factors to be considered in the selection of teeth to be extracted include abnormal tooth morphology, severe carious involvement, advanced periodontal disease, pulpal and periapical pathology, short root length, and bone loss. These factors should be considered in light of the treatment goals. For example, it is better to perform endodontic treatment on one molar rather than extract the tooth and create an asymmetry. Bilateral extraction of the first molars can result in inadequate anchorage and thus inadequate orthodontic treatment.

Subdivision cases and other asymmetrical posterior occlusions may require the extraction of a second premolar on one side and a first premolar on the other side. Some asymmetrical occlusions can be treated with only a unilateral premolar extraction.

Discrepancies in the mesiodistal diameters of the teeth can lead to increased or decreased overjet and to discrepancies in the dental midpoint relationship. These tooth-sized variations can be solved or minimized by careful selection of the teeth to be extracted. For example, in a patient with large lower incisor mesiodistal diameters, sometimes one lower incisor can be extracted. A diagnostic wax setup or the use of the occlusogram is a necessary prerequisite in checking occlusal detail before unusual extraction patterns are implemented.

Patient RR showed a Class I occlusion with incisor crowding and with the lower incisor midpoint to the right of the upper incisor midpoint (Fig 7-15). Tight lips and tight buccinators dictated that the original arch form be maintained without flaring the incisors, even though the lips tended to be retrusive at the beginning of treatment. The arch length–tooth size discrepancy was determined from the occlusogram (Fig 7-15c). Four first premolars were removed to solve the arch-length inadequacy. The red buccolingual line on the occlusogram shows the desired position of the first molars at the end of treatment. Comparison of the before- and after-treatment lateral headfilm and occlusogram tracings shows that the lower incisor position was maintained while the molars were brought forward as planned; the lower dental midpoint was moved to the left to the treatment midline (Figs 7-15d and 7-15e). Maintenance of the lower incisor position required upper incisor retraction, which—along with nose growth—unfavorably affected lip protrusion. Flaring of the lower incisors was not considered a stable alternative. The backward rotation of the mandible, along with an increase of the vertical dimension, was an undesirable byproduct of vertical forces during space closure. Patient RR is a fairly typical example of extraction therapy where four first premolars were extracted, reciprocal mechanics were used between the anterior and posterior teeth, and symmetrical mechanics were employed throughout treatment.

Fig 7-15 Patient RR. Typical extraction pattern of four first premolars to solve an arch-length inadequacy. a, Facial photos, before and after treatment. b, Study casts, before and after treatment. c, Treatment plan occlusogram, showing the arch length inadequacy (black line) and the necessary protraction of the first molars with first premolar extraction (red line). d, Lateral headfilm tracings, before and after treatment. e, Occlusogram tracings, before and after treatment.

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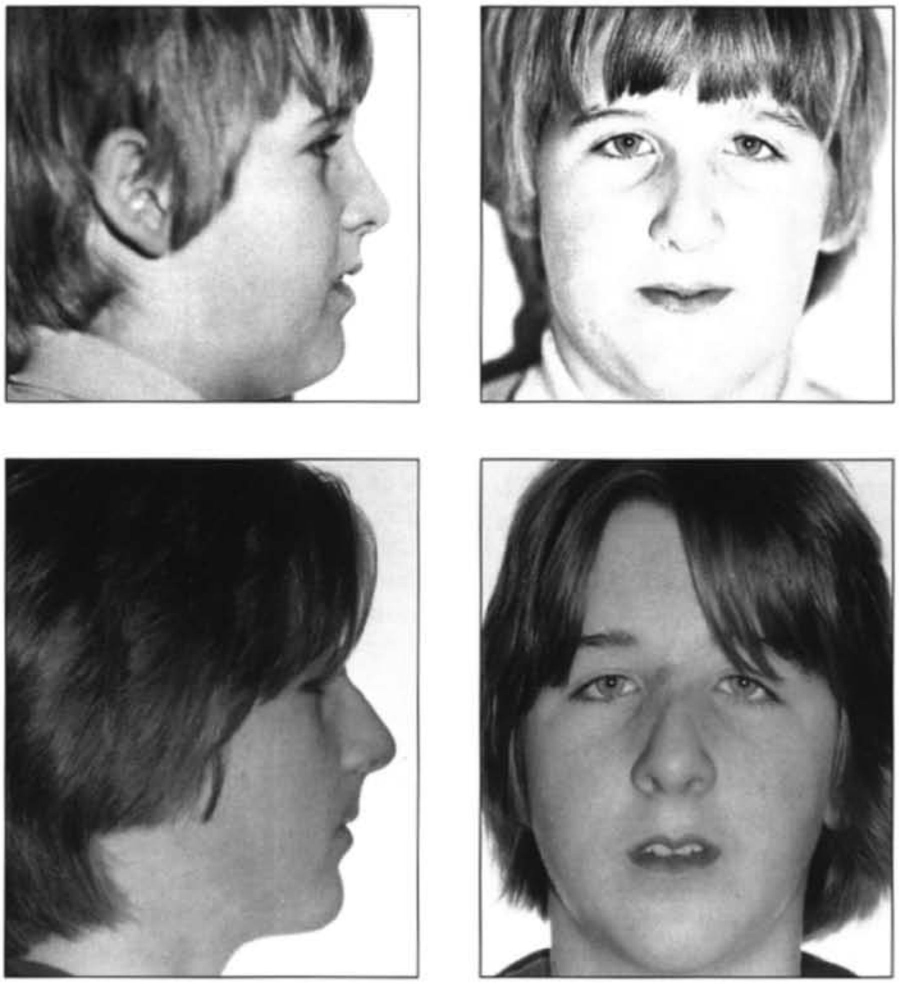

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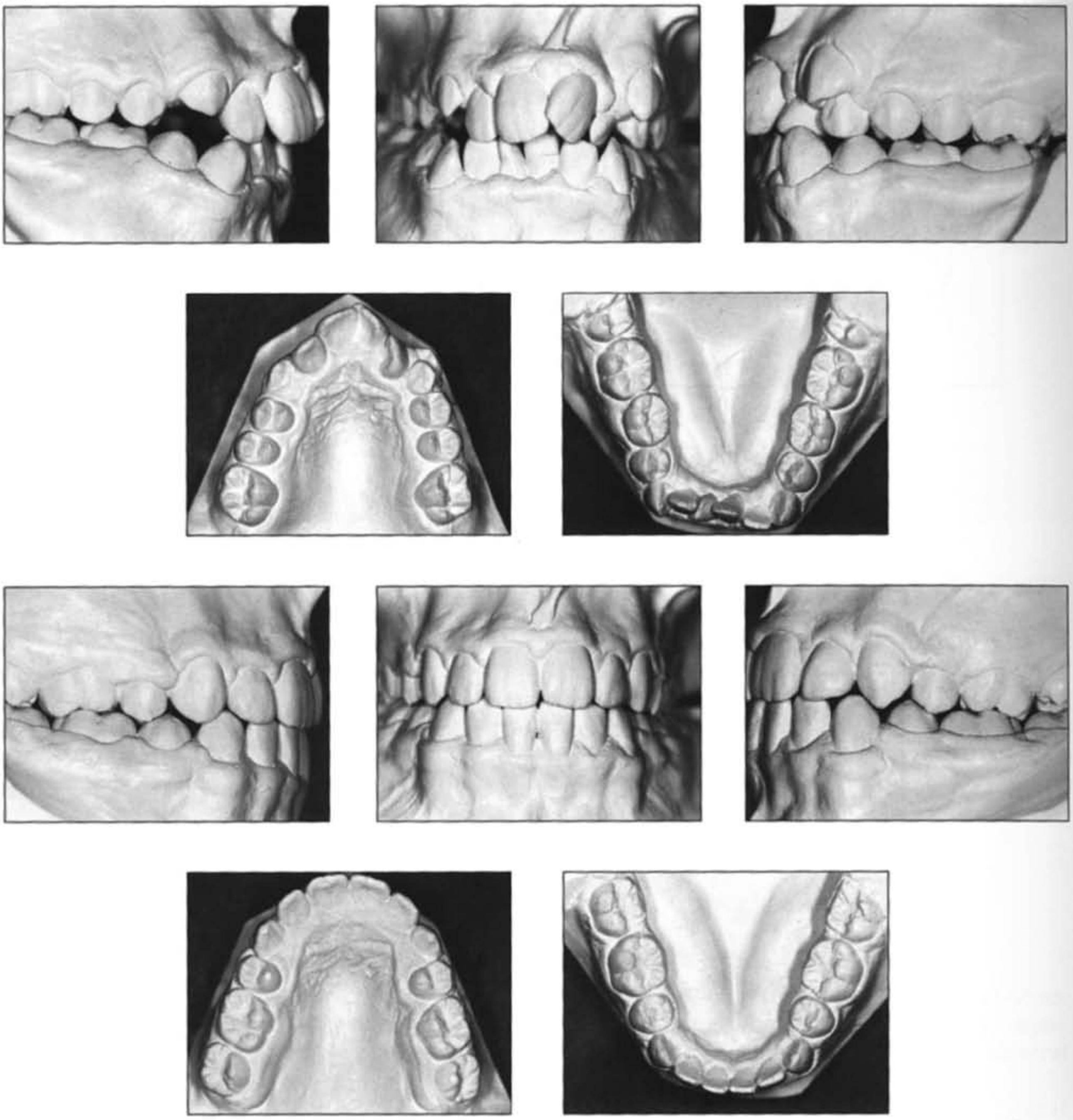

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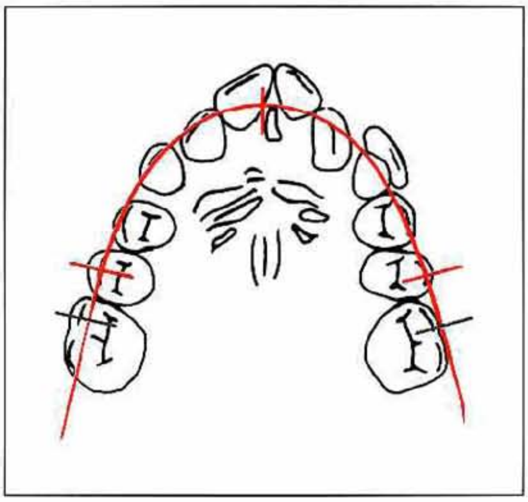

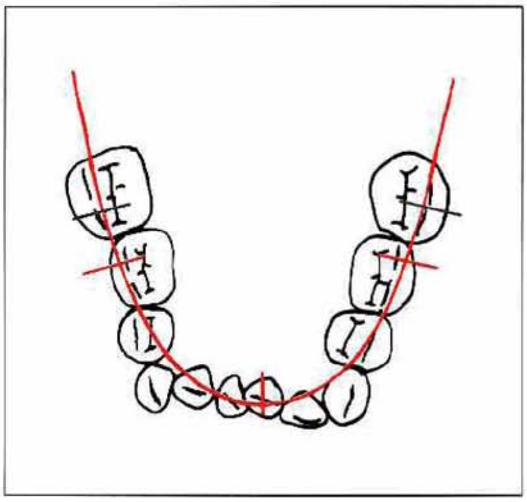

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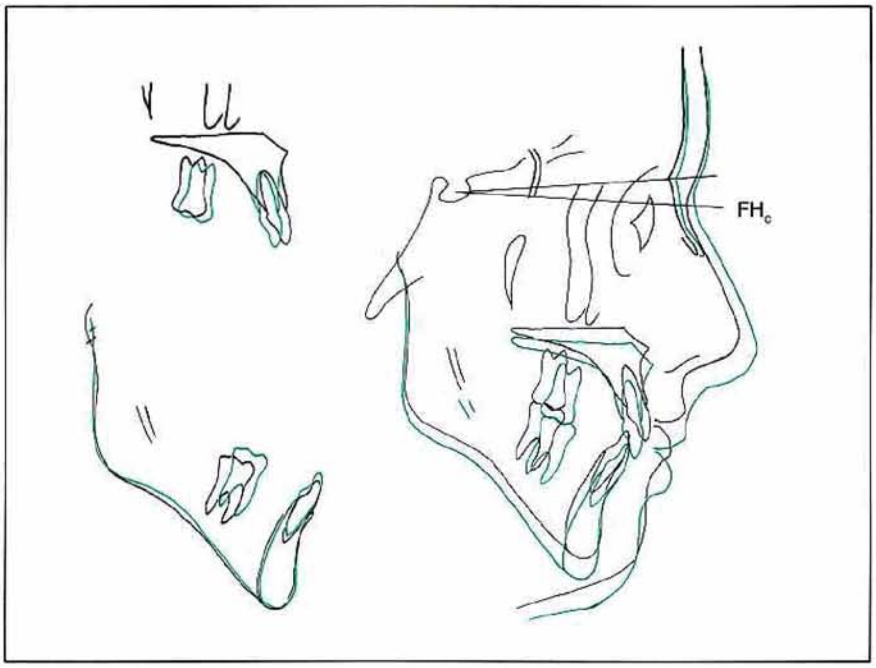

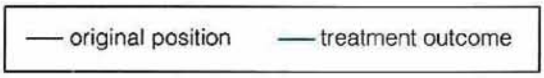

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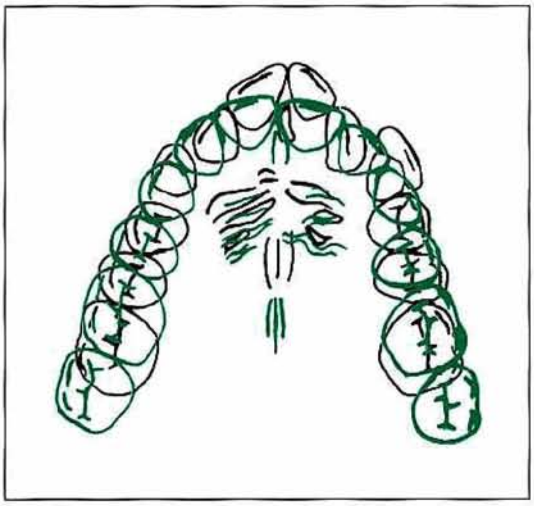
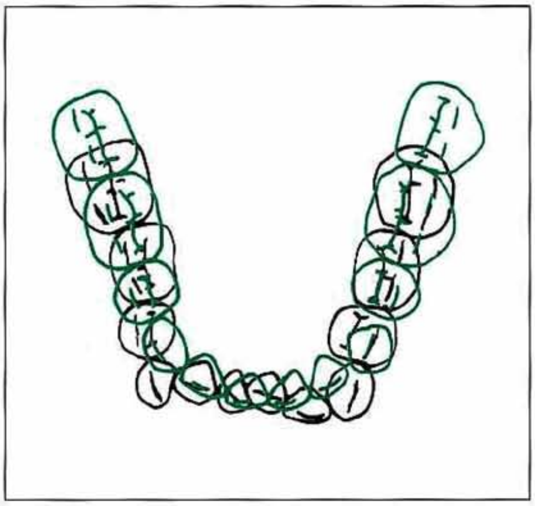


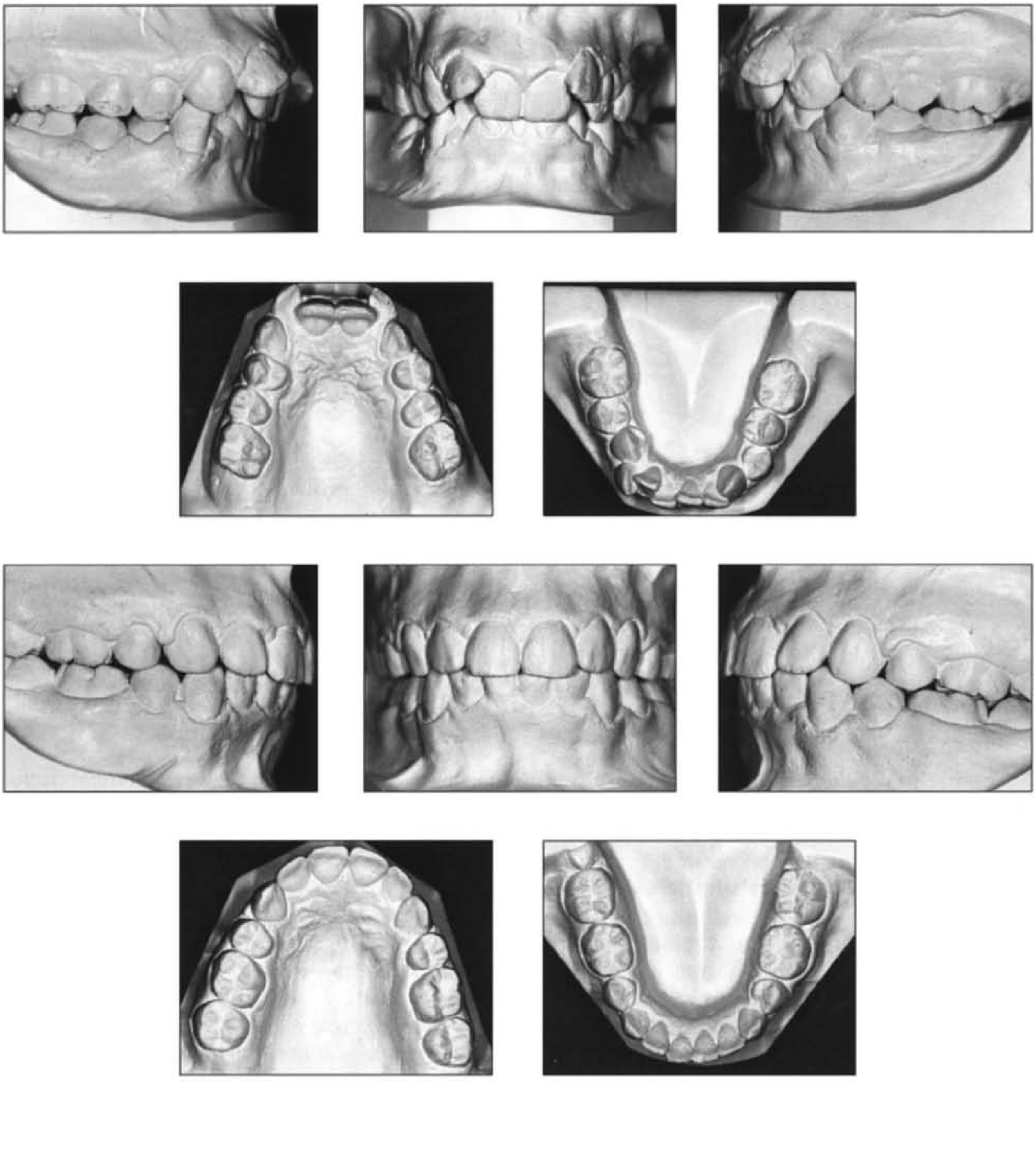


The use of a differential extraction pattern in the upper and lower arches—such as two upper first premolars and two lower second premolars in a Class II patient or vice versa in a Class III patient—can be beneficial. Patient KS, a 10-year 10-month-old female, was treated with differential extractions: the upper first premolars were extracted to facilitate incisor alignment while the lower second premolars were extracted to minimize the retraction of the lower incisors (Fig 7-16). Treating this patient without removing any teeth would have led to two problems: (1) solving the arch-length inadequacy without flaring of the lower incisors or canine expansion and (2) the mechanics of correcting the asymmetrical occlusion. The latter is more easily handled by asymmetrical space closure rather than by unilateral distal movement of the posterior teeth.

Superpositions of the before-after lateral cephalometric headfilms and occlusograms show that the mandibular lower incisor position was maintained (Figs 7-16b and 7-16c) while asymmetrical posterior mesial movement corrected the occlusal asymmetry. The lower molars came forward equally and the upper left molar was protracted more than the right molar. How was the Class II occlusion corrected if no upper and lower differences in molar displacement occurred? The

Fig 7-16 Patient KS. The upper first premolars were removed to facilitate upper incisor alignment and the lower second premolars were removed to facilitate lower buccal protraction rather than lower incisor retraction. Symmetrical space closure occurred in the lower arch while the upper left first molar was advanced more than the upper right first molar to correct the asymmetrical occlusion. a, Study casts, before and after treatment. b, Lateral headfilm tracings, before and after treatment. c, Occlusogram tracings, before and after treatment.

a.



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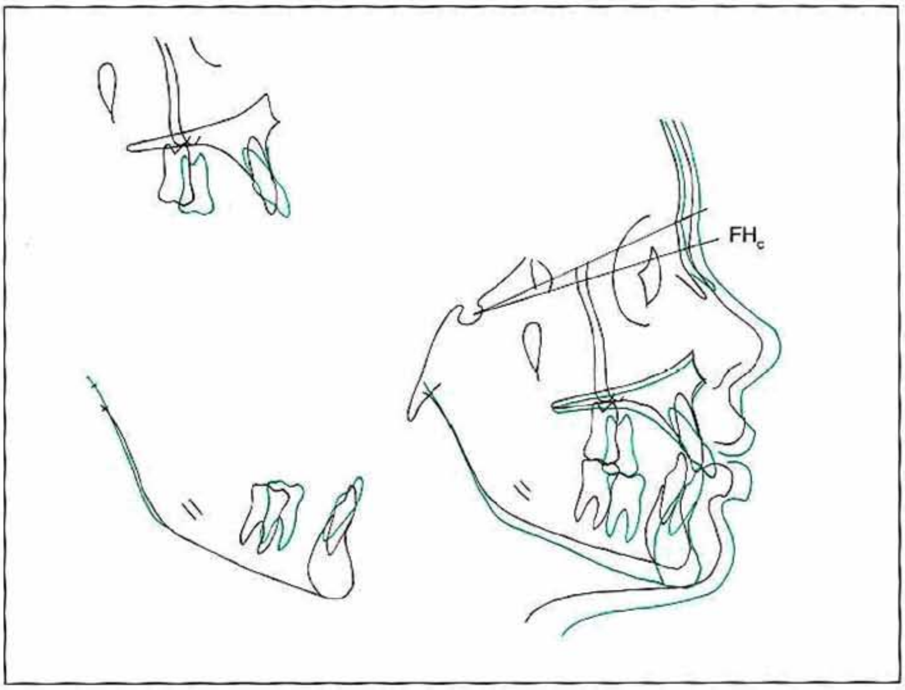

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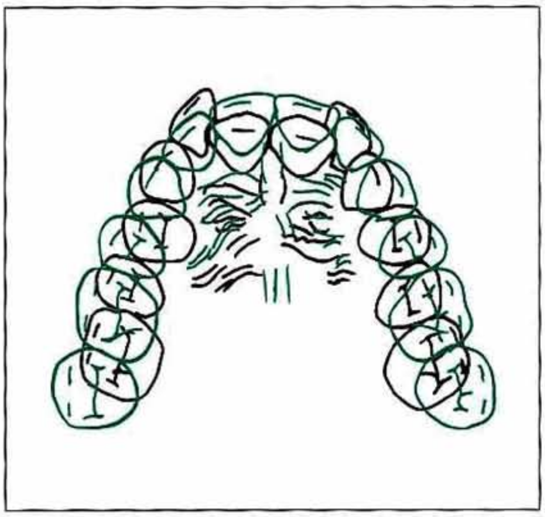
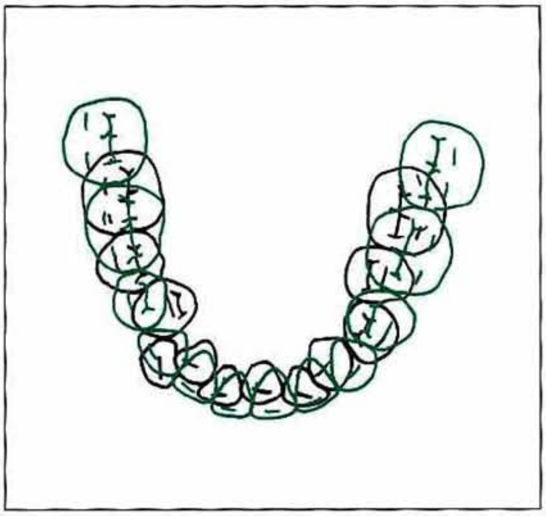
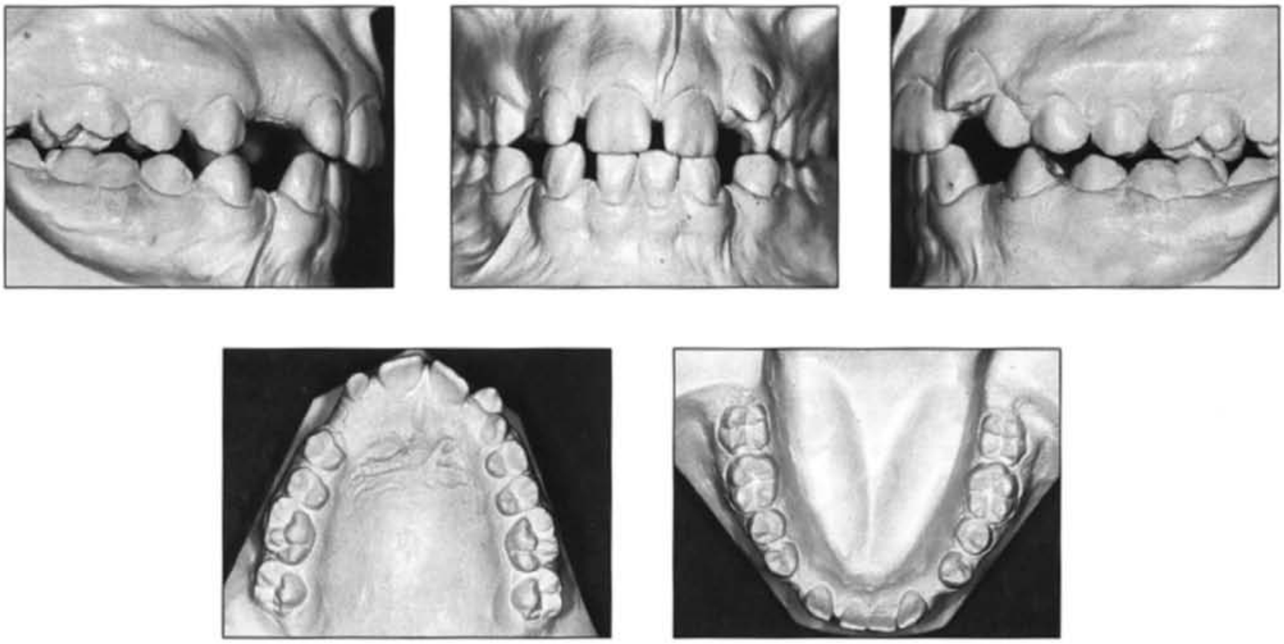




— original position — treatment outcome

Fig 7-17 Patient JG. The upper left lateral incisor and the lower right and left lateral incisors are congenitally missing. The remaining upper right lateral incisor is peg-shaped and was removed to maximize anterior retraction and to preclude a prosthetic replacement. Although not ideal, the final result is esthetically acceptable. a, Before-treatment study casts. b, After-treatment study casts.

a

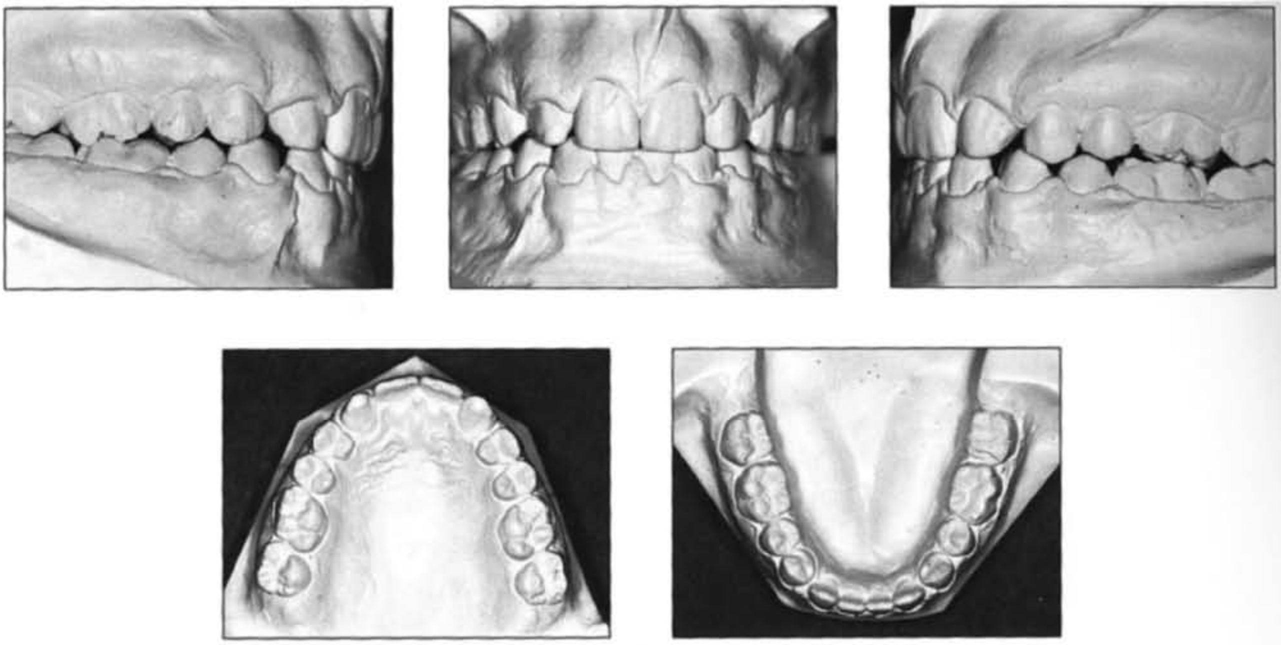


superposition of the before- and after-treatment lateral tracing provides the answer: marked differential growth between the maxilla and the mandible (3 years 11 months passed between the initial and deband headfilms). Point B moved forward of point A by 4 mm relative to the occlusal plane. Of course, this is not an orthopedic change, but rather normal growth; some Class II elastics were used minimally in treatment.

Atypical extraction patterns are required in patients with missing teeth. Patient JG, a 13-year 1-month-old female, was missing an upper left lateral incisor and two lower lateral incisors (Fig 7-17). A decision was made to extract the peg-shaped upper right lateral incisor and close the resulting spaces, thereby reducing the incisor protrusion and precluding the need for a bridge or implants. The finished result shows the canines in the position of the lateral incisors. The esthetics, while not perfect, were very acceptable to the patient.

Patients who are missing upper lateral incisors may be treated by either closing the spaces or widening them sufficiently for a bridge or implant. In deciding which to do, one should consider factors other than prosthetic considerations and incisor esthetics. If the patient has a Class II occlusion and a good lower arch, space closure and treatment to a Class II occlusion may be the best choice.

b



An occlusogram analysis is particularly helpful in instances of mutilated dentitions, multiple missing teeth, and asymmetrical posterior occlusions. The determination of the arch-length problem by quadrant leads to the best decisions on extractions, if needed, and the asymmetrical tooth movement required.

An alternative to extraction is reduction of the mesiodistal diameters of the teeth, also known as *reproximation*. Reproximation can be useful in patients who have tooth-sized discrepancies or a very small arch-length inadequacy. Some orthodontists will use this procedure even in situations where there is a large tooth-sized discrepancy, carefully reducing the mesiodistal diameters and recontouring the crowns so that an ideal occlusion can be produced. In evaluating a patient, many times an orthodontist will ask the question, "Is this an extraction or nonextraction patient?" Using the procedure outlined here, where one makes decisions sequentially, this question of extraction versus nonextraction is answered near the end of the planning sequence. In one sense this is a fairly simple decision since all of the important factors, from growth through arch widths and desired anteroposterior position of the lower incisors, have already been determined. For some, orthodontic treatment planning is reduced to a simple question: extraction or nonextraction. This can lead one astray since it is important to define treatment objectives first.

Fig 7-18 Patient JY. An arch-length redundancy in the presence of a large tongue required the maintenance of the incisor position and subsequent protraction of the posterior teeth. a, Facial photos, before and after treatment. b, Study casts, before and after treatment. c, Tracing of the lateral headfilm. d, Occlusogram treatment plan. e, Occlusogram tracings, before and after treatment.

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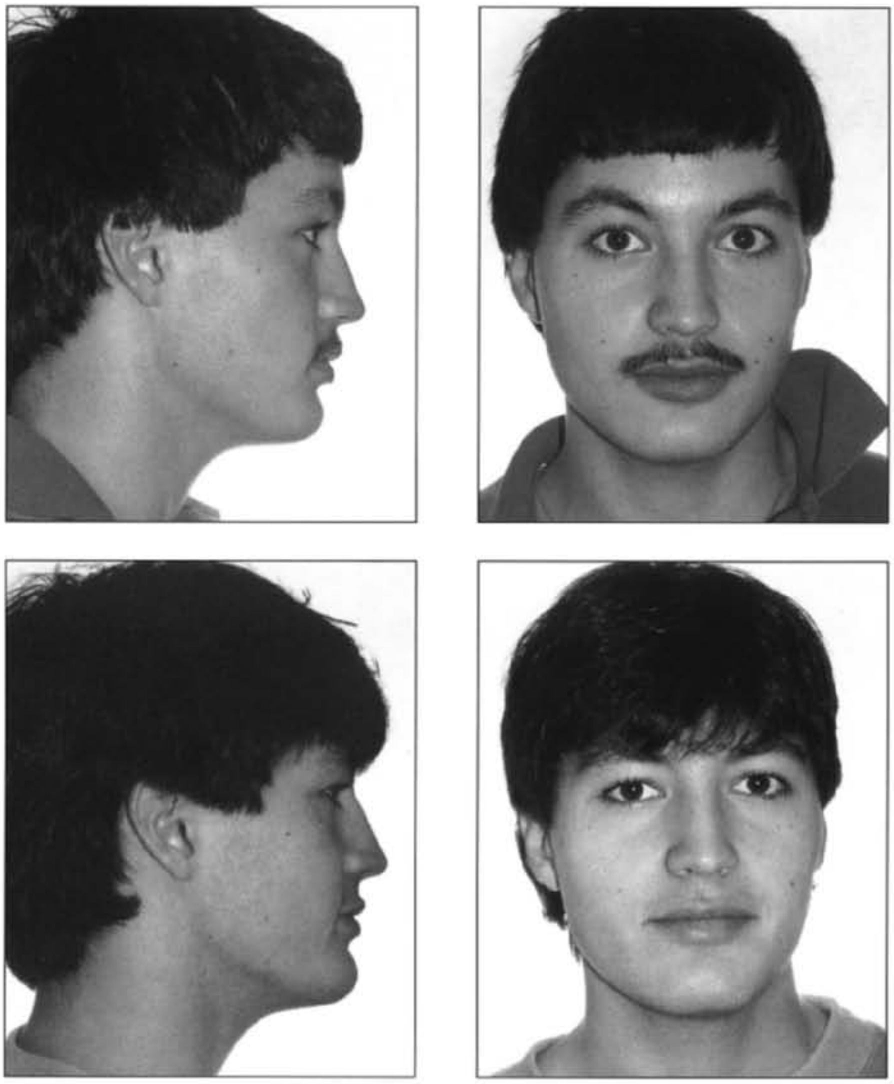
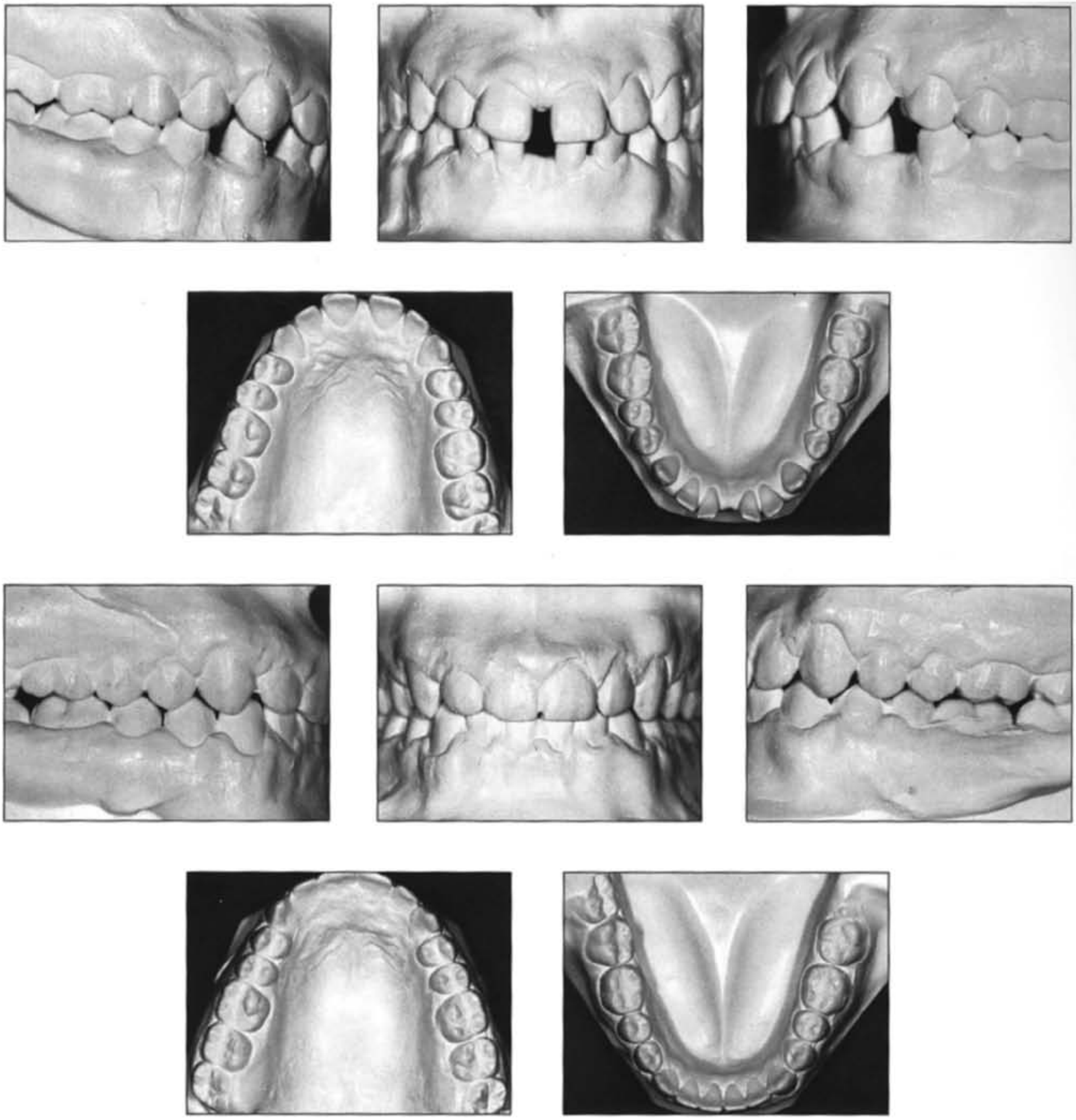


Arch-Length Redundancies

At the other end of the spectrum from arch-length inadequacies are the malocclusions caused by excessive arch length. While reciprocal anchorage retracts anterior teeth and protracts posterior teeth equally, the mechanics may be simple. The stable solution for many of these patients, however, will require maintaining incisor position while protracting the posterior teeth—procedures that can challenge the clinician.

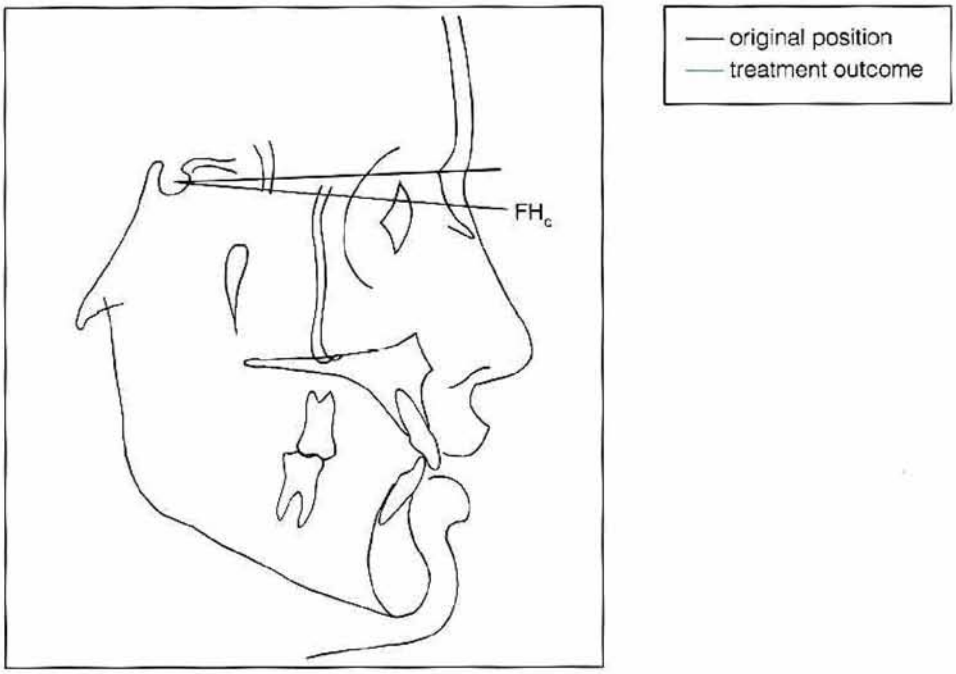
Patient JY, a 20-year 3-month-old male, exhibited generalized spacing in the upper and lower arches with a Class II occlusion (Fig 7-18). The treatment goal was to maintain the incisors in their original anteroposterior position to accommodate a large tongue and to minimize the retrusion of his lips (Figs 7-18a and 7-18c). The treatment plan occlusogram shows that upper molars must be brought

b



forward 2 mm (Fig 7-18d). The protraction required in the lower arch is nearly the full width of a premolar. Superposition of the before- and after-treatment occlusograms demonstrates that the treatment objectives were met; note the dramatic protraction of the lower posterior segments (Fig 7-18e). Differential moments with "T" loops were used during space closure along with Class II elastics. Although the mechanics in this patient were complicated, they were necessary to maintain incisor position and to close the generalized spacing by protraction of the posterior teeth. The wide mandible and the large tongue dictated the maintenance of the arch form and the canine width.

c



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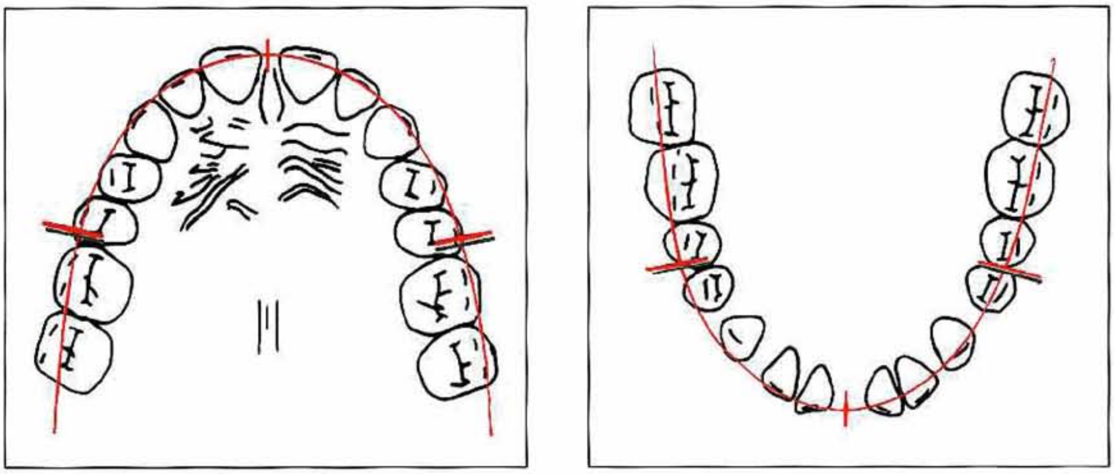

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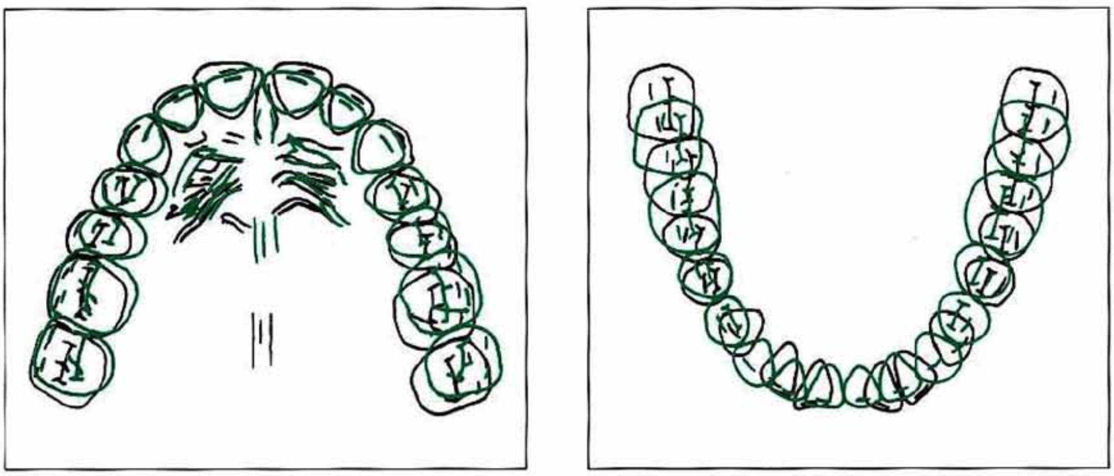
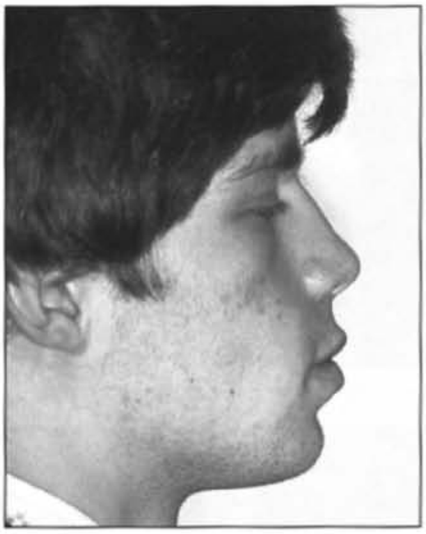
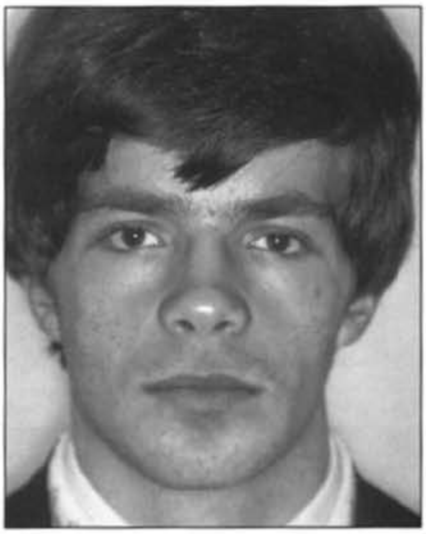


Fig 7-19 Patient CB. A Class III malocclusion in centric occlusion. a, Facial photos, after treatment. b, Before- and after-treatment study casts in centric relation. c, Before- and after-treatment tracings of the lateral headfilm. d, Treatment-plan occlusogram. e, Occlusogram tracings, before and after treatment. Mandible continued to grow forward during treatment. The upper incisor position was maintained and the upper posterior teeth were protracted; in the lower arch, the incisors were retracted to solve the arch-length redundancy and to produce normal overjet, overbite, and alignment.

a

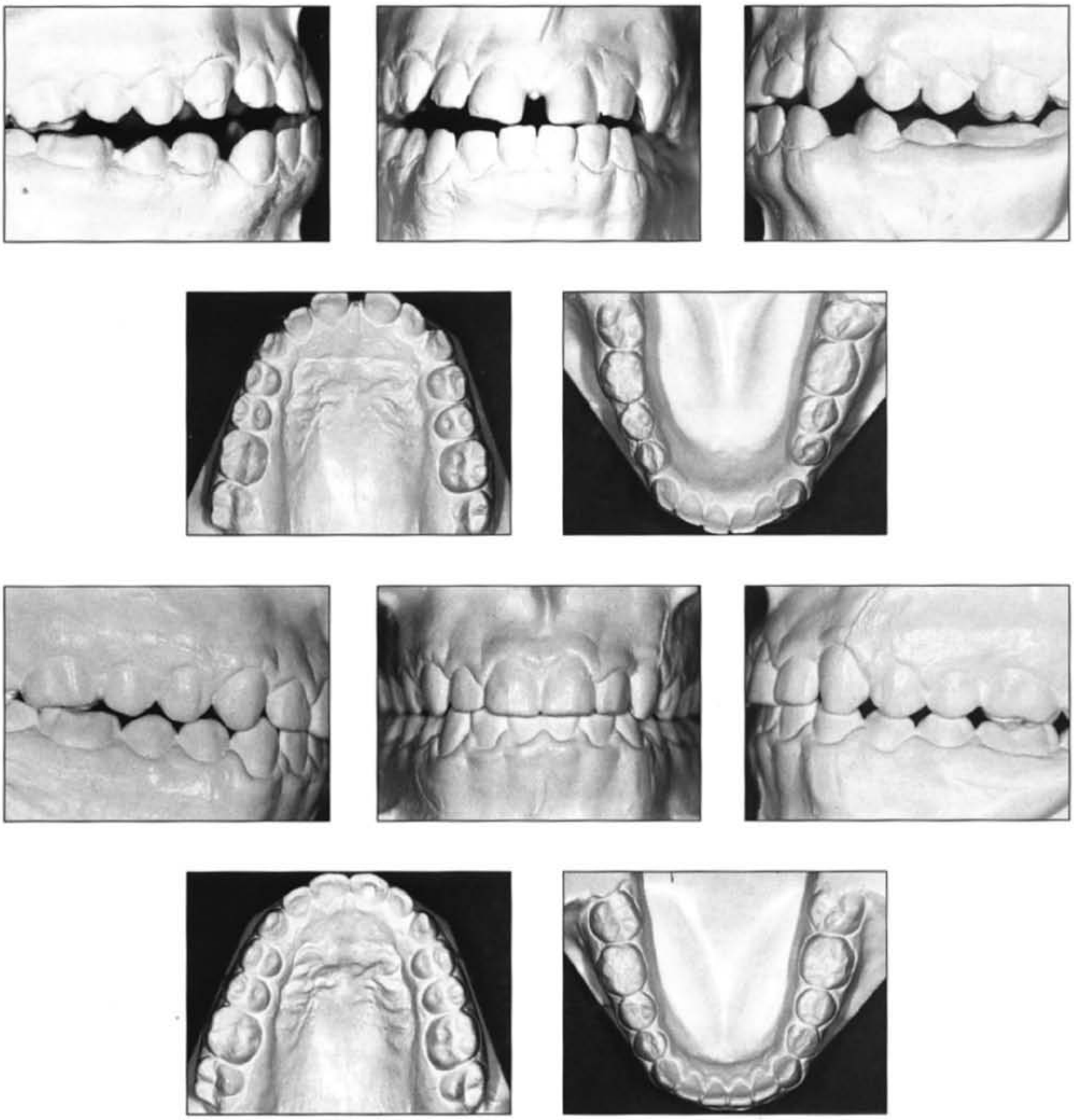




Patient CB presented with a Class III occlusion in centric occlusion and a Class I occlusion in centric relation; spacing existed in both arches (Fig 7-19). Unlike patient JY, the lower incisors were stable in their protrusive position only because incisal forces maintained them in an anterior crossbite relationship. The arch-length redundancy in the lower arch was solved through retraction of the lower incisors and molar protraction (Figs 7-19c to 7-19e). Although the patient was 15 years 9 months old at the beginning of treatment, mandibular growth continued over the 1-year 3-month treatment period.

The determination and solution of any arch-length problem completes the positioning of the teeth at the end of treatment. From this framework the detailed occlusion and other special problems that may be present can be considered. The key to setting orthodontic goals is to establish this basic framework without getting lost in the occlusal details of the case.

b



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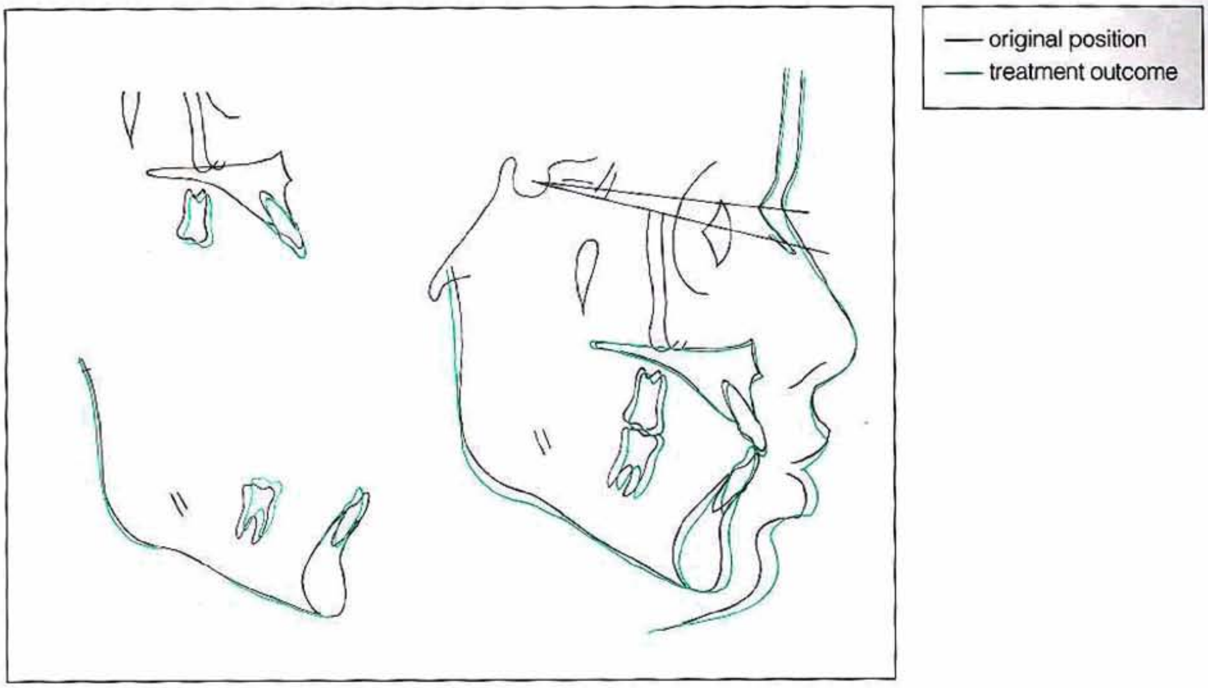

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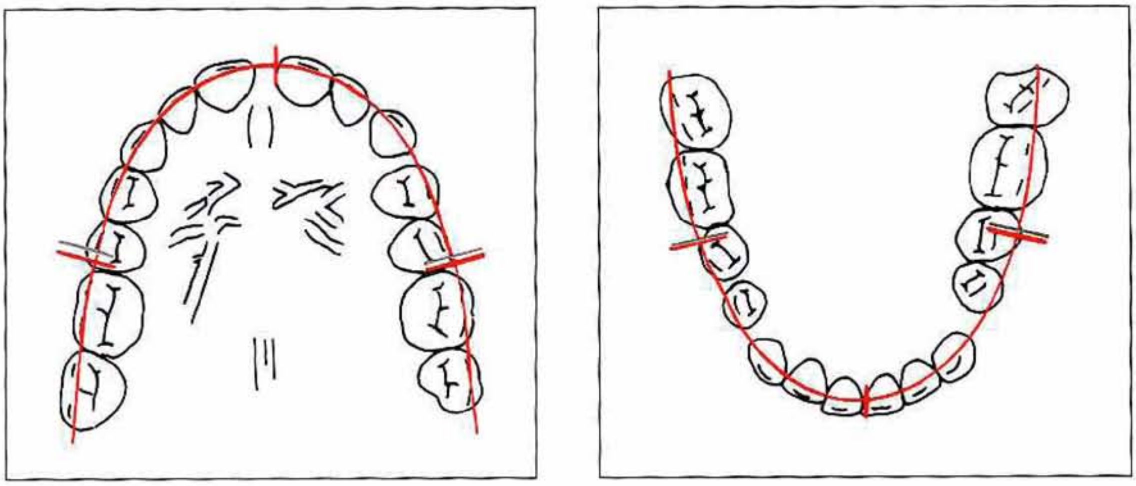

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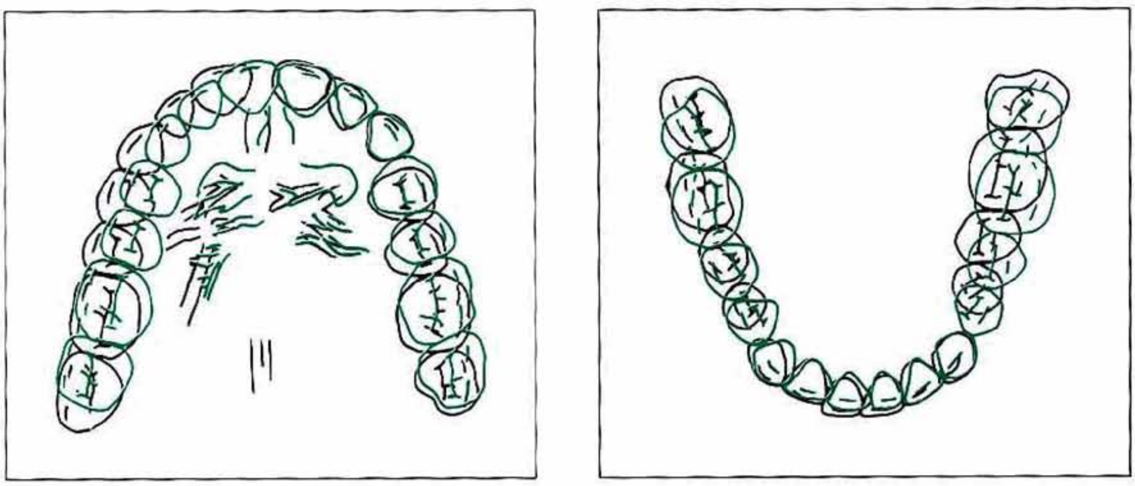

Epilogue

If you don't know where you are going, any road will get you there.—M.N. Chatterje, Indian sage

Comprehensive treatment planning is fundamental to successful orthodontic treatment planning. The basis of any treatment plan is the establishment of relevant treatment goals, which summarizes the theme of this book. Before a building can be constructed, an architectural plan or blueprint is needed; superior blueprints result in faster and more cost-efficient construction. The orthodontist is, in a fashion, a dentofacial architect who needs superior "blueprints" in order to produce successful treatment.

Is a full treatment plan necessary if limited, partial, or compromise treatment is to be performed? Mistakes will be avoided if full consideration of all goals is given to every patient. Such consideration may not require detailed treatment-plan tracings, but it should, at a minimum, include a checklist of such core goals as skeletal changes, occlusal plane considerations, arch-form midpoint, and arch-length modifications.

Medicine that deals with disease is problem-oriented. Although the creation of a problem list is an important step in the orthodontic database analysis, when used as the basis of a treatment plan, it can distort the overall plan. While it is true that the problem list is addressed in the plan, a comprehensive treatment plan goes well beyond the problem list. A patient's problem may be only an arch-length inadequacy with crowded teeth, but good treatment can alter the occlusal plane, the arch form, the anteroposterior incisor position, or the incisor midpoints, areas that may not have been considered problems by the patient or the orthodontist.

A common error is to base an orthodontic treatment plan on the Angle classification rather than on fundamental treatment goals. There are no chapters in this book on Class I, Class II, or Class III treatment. If distal movement of the posterior teeth is a possibility, the factors to consider are independent of the Angle or any other classification system. Principles of extraction therapy apply equally to Class I, Class II, and Class III patients.

The Detailed Plan

An architectural blueprint includes the basic details of a building: dimensions, number of floors, number of rooms, and so forth. Other details—eg, wallpaper, trim, fixtures, furniture—can be added later. In this book, the primary treatment plan and factors to be considered in developing it have been clarified; the details can then be added to the plan.

Detailed occlusion and intercuspation may present special problems. Tooth size and shape discrepancies may require reproximation, reshaping, or arrangement of the teeth in a non-Angle occlusal intercuspation.

High or impacted canines or other unique problems may be present. It is best to develop the comprehensive treatment plan first and plan the solution to a local problem later. For example, in a mutilated dentition with many missing teeth, it is useful to develop an initial treatment plan as if all the teeth are present and no drifting has occurred to ensure that the major treatment goals have not been omitted.

Multiple Plans

No treatment plan is ideal, and unexpected problems can occur. For example, treating to a stable incisor position could well produce lips regarded as too retrusive. For this reason, it is advisable to prepare two or more reasonable plans with different goals. These plans can be evaluated by the patient and the orthodontist, and the best plan for the patient can be selected. Treatment plans can have fundamentally different treatment goals; for example, one treatment goal could be based on an orthognathic surgical procedure and another could be based on orthodontic treatment only. Conversely, two treatment plans could be fundamentally the same, the only difference being in the details; for example, the space of a missing lateral incisor could either be opened for a fixed partial denture or closed orthodontically. In such a patient, considerations of the facial skeleton, occlusal plane, arch form, and midline determination could all be the same.

The chapters in this book are arranged in the sequence best followed for establishing goals; that is, from general to specific goals (skeletal through arch length). Of course, this does not mean that steps cannot be retraced or that a treatment plan cannot be scrapped and started over from the beginning. It is better to optimize a treatment plan at the beginning using paper and tracings than to alter goals during treatment or to retreat the patient.

Beyond the Basic Plan

Orthodontics today does not operate as an isolated specialty; quality results require an interdisciplinary effort. Prosthetic considerations include altered crown morphology, fixed partial dentures, and implants. Combined orthodontic and periodontal therapy can increase the life of the dentition. Orthognathic surgery and distraction osteogenesis have made possible stable, esthetic results not possible through orthodontics alone. A relationship with our medical colleagues can be based on treating both healthy children and those who have specific problems, such as airway obstruction. In the future, drug therapy may be used to enhance growth and tissue response during tooth movement. Interdisciplinary treatment also means more than making referrals to a general practitioner or specialist; it requires good communication and integration using a team approach to treatment.

The term *plan* has two meanings applicable to orthodontics. The first meaning refers to a scheme of arrangement—this is the blueprint mentioned earlier. It includes the arrangement of bones and teeth in three-dimensional space and, along with time, makes it four dimensional. The possibilities of muscle alteration and function must also be considered. The second meaning refers to action. A plan of action has two components: the sequence of treatment (sequence plan) and the mechanics. Most orthodontics currently is achieved by means of the application of forces to teeth to reach treatment goals. Beyond appliances, functional therapy and, in the future, drug therapy can be considered.

During treatment the original treatment goals must be continually reevaluated. Unpredicted growth, lack of patient cooperation, and variation in mechanotherapy can require a change in treatment goals. At every stage in therapy the orthodontist must determine where the teeth and bones are in relation to the original goals, making orthodontic therapy highly interactive in nature.

At the end of treatment, the outcome should be evaluated using cephalometric radiographs and occlusograms, and the treatment plan should be compared to the actual changes that the patient has undergone. The outcome evaluation is an important step in designing the retention phase and minimizing postretention complications. It is also a learning experience for the clinician to understand how the malocclusion was corrected or the reasons for failure. For example, although some clinicians might think that a headgear moves molars distally for the correction of a Class II occlusion, in truth, mandibular growth is usually responsible for Class II correction.

Goal-oriented orthodontic therapy may seem obvious; nevertheless, treatment is sometimes carried out with limited goals or no goals at all. Even worse is when the orthodontic appliance itself determines the goals for the patient. For example, how would one correct a posterior

crossbite? With criss-cross elastics, allowing the elastics to determine molar position rather than the molar position being a planned goal. How to correct a deep overbite? Use a curve of Spee in the upper and a reverse curve of Spee in the lower arch wires. How to correct a Class II occlusion? Use a headgear or functional appliance or some other favorite appliance. These are examples of appliance-driven orthodontics. The biomechanics and the appliances should be used to reach treatment goals, not vice versa.

New knowledge is continually added to our understanding of growth, tissue response, stability of treatment, and biomechanics. With it, orthodontic treatment goals will be enhanced and the current goals will be broadened, giving our patients improved dental health, pleasing facial and dental esthetics, enhanced treatment stability, and restoration of normal jaw function.

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Appendixes

Appendix A
Mesiodistal Diameters of the Permanent and Deciduous Teeth

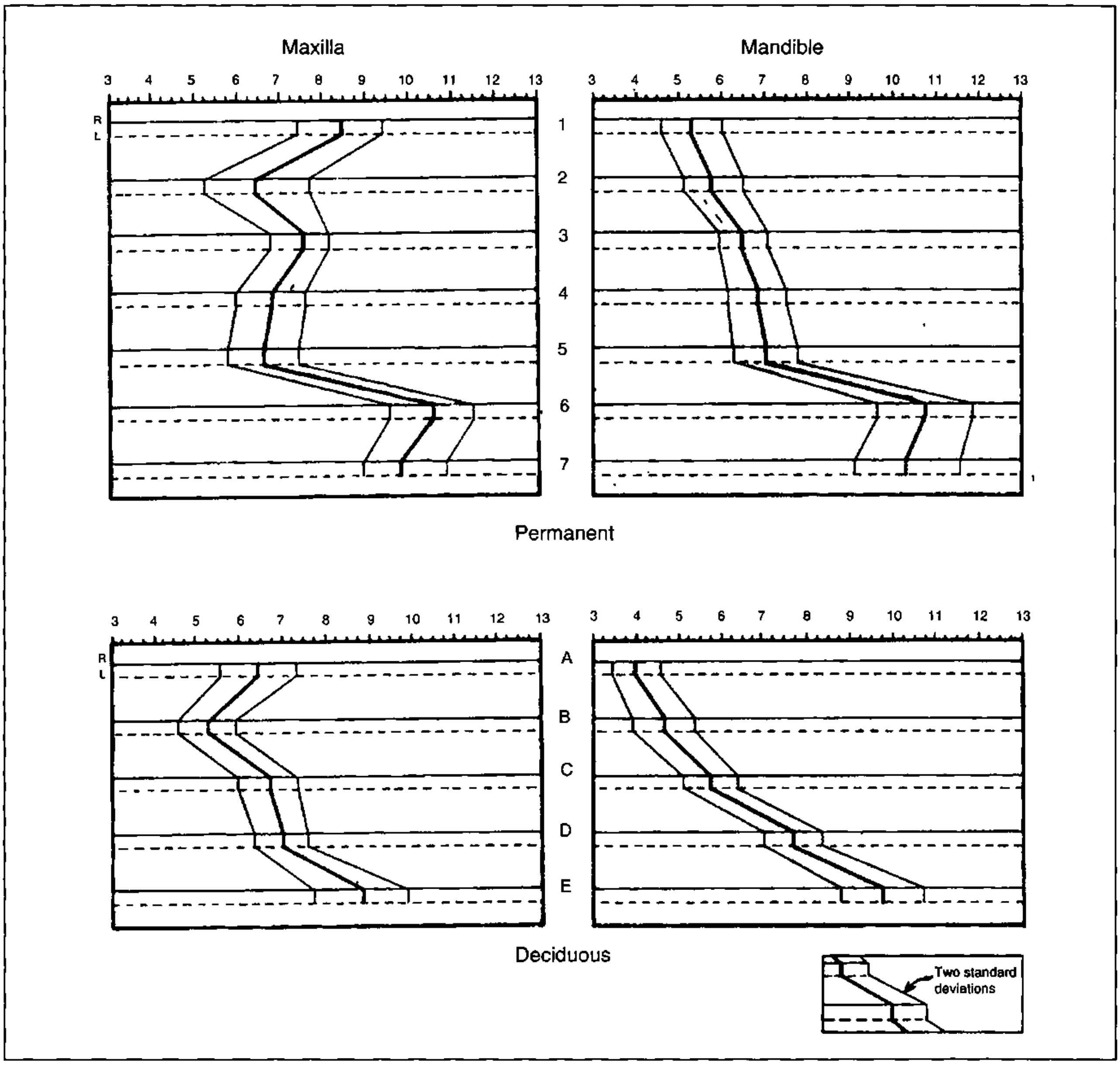


Fig A-1 Mesiodistal diameters of permanent and deciduous teeth—female.

The mesiodistal diameters of a patient's teeth can be compared to standard diameters of male and female teeth (Figs A-1 and A-2). These "wiggle diagrams," based on the Moorrees's standards, allow one to plot the mesiodistal diameters of the teeth and to determine quickly whether they fall within the normal range. (They also show two standard deviations on both sides of the mean.) (See Moorrees, *The Dentition of the Growing Child.*)

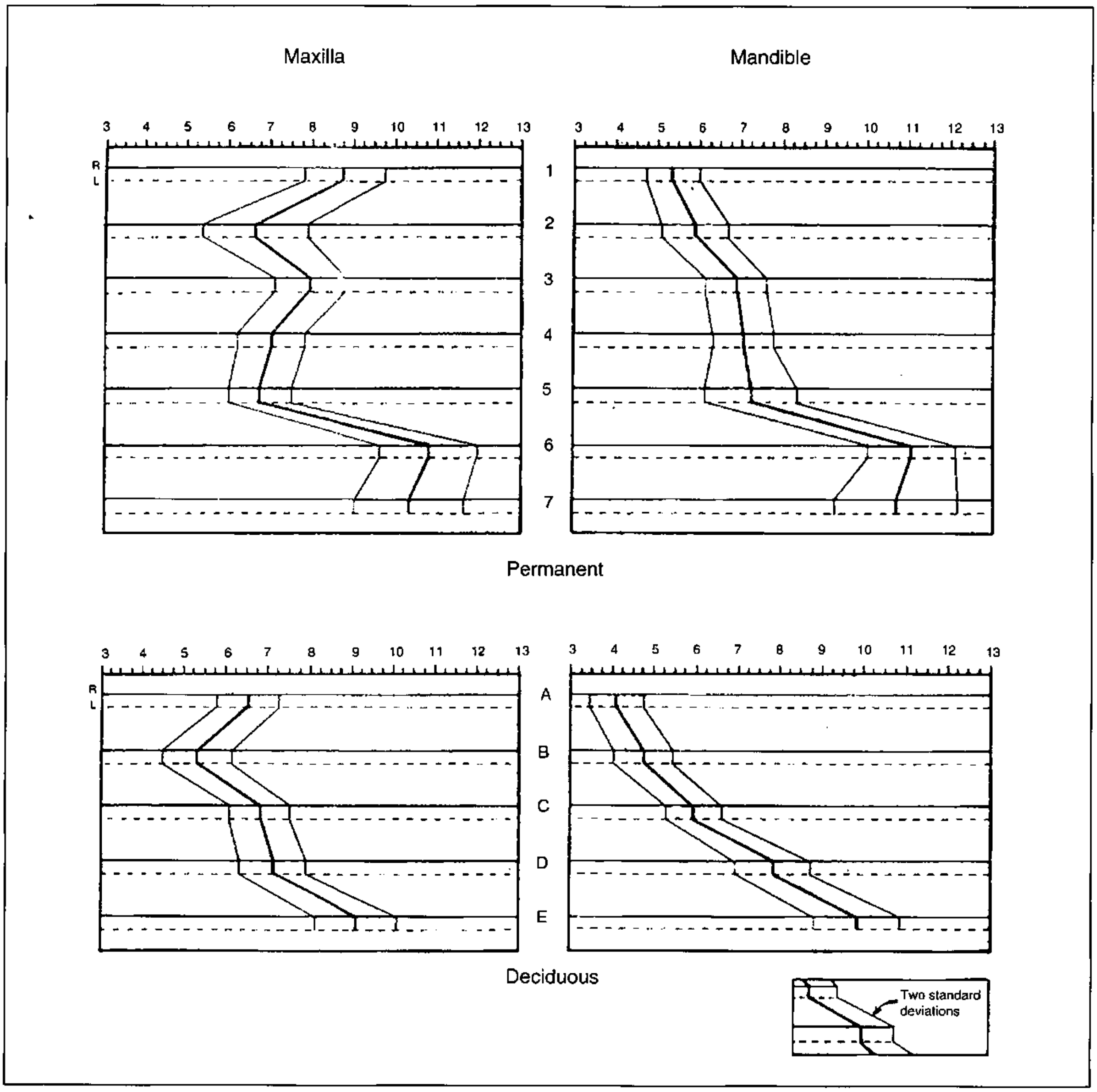


Fig A-2 Mesiodistal diameters of permanent and deciduous teeth—male.

Appendix B
Comprehensive Cephalometrics: Methods and Standards by Age and Gender

Cephalometrics was developed as a means of determining the extent of the skeletal and soft tissue involvement in a malocclusion. The lateral cephalometric view has been the most popular, although the frontal view is being used more and more because of the information that can be gleaned from it. In cephalometric analyses, the skeletal components of a malocclusion are examined with regard to their size, position, and angular orientation. Knowledge of the basic cephalometric landmarks and measurements is assumed. Before making any measurements on the tracing of the lateral cephalometric headfilm, a horizontal reference line should be drawn. Frankfort horizontal extends from pogonion, a variable soft tissue landmark, and orbitale, both of which can be difficult to find.

Although it would be more convenient to use the sella-nasion line, which is clearly visible, typically this line is not horizontal. Therefore, a constructed Frankfort horizontal (FH_c)—that is, a line 7 degrees less than the sella-nasion line, as suggested by Burstone—is used as the horizontal reference line. The records and standards in this text have all been based on this adjusted sella-nasion line, which is parallel on average to the Frankfort horizontal line.

In these appendixes, (FH_c) indicates that a particular measurement is made parallel to the constructed Frankfort horizontal line, whereas (pFH_c) indicates that a measurement is made perpendicular to the FH_c line. To construct a line perpendicular to the FH_c line, place the tracing over millimeter graph paper so that the FH_c line is positioned directly over a dark horizontal line and nasion is positioned directly over a dark vertical line. The tracing of the lateral headfilm can then be taped into this position over the graph paper and measurements can easily be made parallel to or perpendicular to the FH_c.

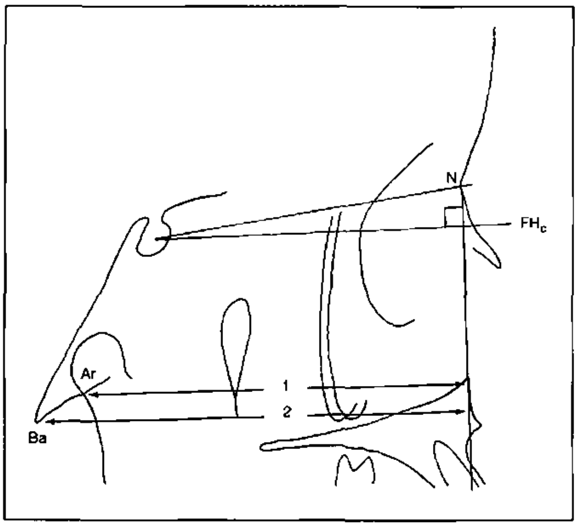
The lateral headfilm used for this cephalometric analysis should be taken with the jaws in the centric relation position and the lips in their resting position. Sometimes there is contact between the lips when they are at rest, but the normal interlabial gap is about 2 mm.

The cephalometric hard tissue measurements, developed by Burstone in 1958, use measurements from other analyses as well as new measurements. For example, the nasion perpendiculars allow comparison of the position of anterior landmarks to a constant horizontal plane (line). In 1968, Burstone and Hickman selected a group of longitudinal headfilms from the Denver Growth Study and used only those that were complete and untreated. A developmental age based on mandibular growth increments was established and the standards were created based on developmental rather than chronological age (see Tables B-1 to B-4). The soft tissue standards are cross-sectional and were collected at Indiana University School of Dentistry (see Table B-5).

A soft tissue profile analysis was developed as an aid to planning orthognathic surgery. The means and standard deviations of 20 male and 20 female Caucasians between the ages of 20 and 30 years are shown in Table B-6.

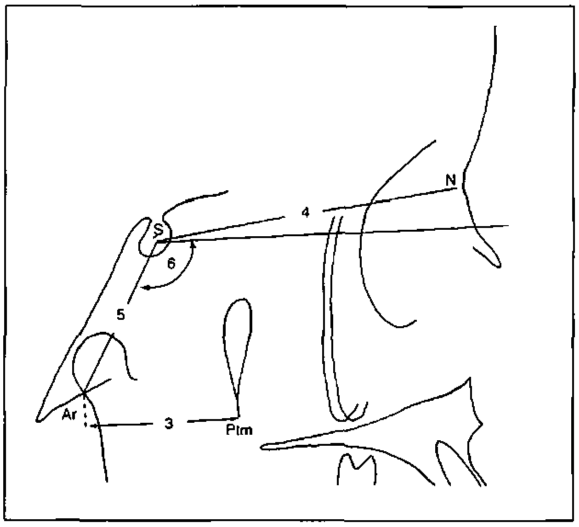
Hard Tissue Cephalometric Measurements

Cranial Base



1. **N-Ar (FH$_c$):** Nasion to articulare measured parallel to the FH$_c$. This line has been used as a measurement of the total cranial base length. Since the mandible is attached to the posterior cranial base, if all other measurements are unaltered and other things are equal, longer cranial base length measurements would position the mandible in a more retruded or retrognathic position. Shorter measurements of the total cranial base length, again other things being equal, would lead to a prognathic or Class III relationship.
2. **N-Ba (FH$_c$):** Nasion to basion, measured parallel to the FH$_c$. This line is also a measurement of the total cranial base measured on the FH$_c$ line. Again, other things being equal, longer measurements indicate a mandible being held further posteriorly to nasion, in a more retrognathic position. Shorter cranial base lengths indicate that the mandible is held closer to nasion in a more prognathic relationship.

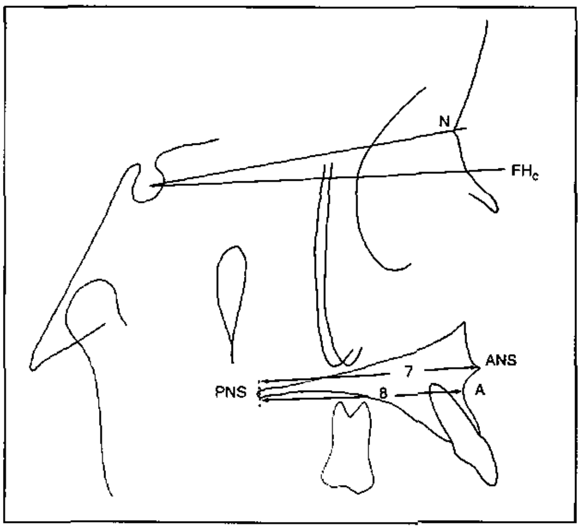
Cranial Base (*cont.*)



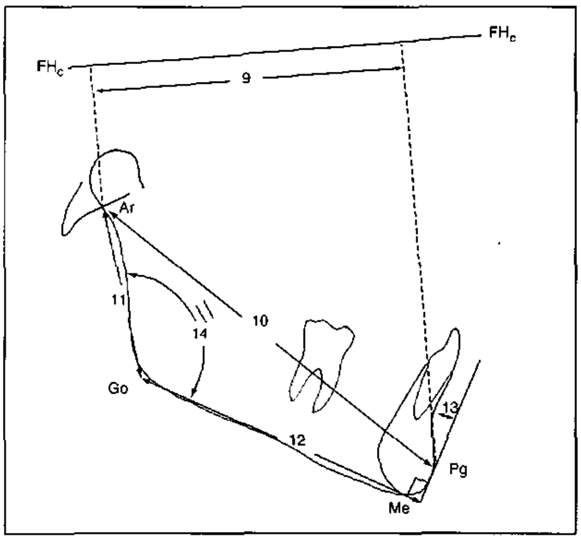
3. **Ar-Ptm (FH$_c$):** Articulare to pterygomaxillary fissure, measured parallel to the FH$_c$. Other things being equal, a large Ar-Ptm (FH$_c$) measurement would indicate that the posterior cranial base is long, positioning articulare (and therefore the mandible) further posteriorly. This could contribute to a Class II skeletal pattern. On the other hand, a short Ar-Ptm (FH$_c$) could be the finding in a prognathic jaw relationship or Class III skeletal pattern.
4. **S-N:** Sella to nasion. This direct measurement of the distance S-N is schematically a measurement of the anterior cranial base length.
5. **(S-Ar):** Sella to articulare. Since the mandible is attached to the posterior cranial base, longer measurements of the S-Ar distance indicate that the mandible is held further posteriorly, other things being equal. This would be a finding in a Class II or retrognathic skeletal pattern and the reverse would be found in Class III or prognathic skeletal patterns.
6. **S-N-Ar:** Nasion to sella to articulare, also called the cranioflexure angle. Since articulare indicates the position of the posterior mandible, a large cranioflexure angle would suggest that, other things being equal, the mandible would be held further posteriorly, leading to a retrognathism. Smaller cranioflexure angles have the reverse effect: they contribute to a prognathic relationship, holding the mandible in a more prognathic relationship.

Maxilla and Mandible

7. **PNS-ANS (FH_C):** Posterior nasal spine to anterior nasal spine, measured parallel to the FH_C. This direct measurement indicates the length of the maxilla: other things being equal, shorter lengths lead to Class III skeletal patterns and longer lengths lead to a Class II or retrognathic skeletal pattern. If one connects the posterior nasal spine (PNS) with the anterior nasal spine (ANS), the palatal plane (line) is formed. The teeth in the maxillary arch can also be related to the palatal plane (line).
8. **PNS-A (FH_C):** Posterior nasal spine to point A, measured parallel to FH_C. This is a measurement of the maxillary denture-bearing area. Even with longer than average maxillae, the maxillary denture-bearing area could be of average or shorter than average length.

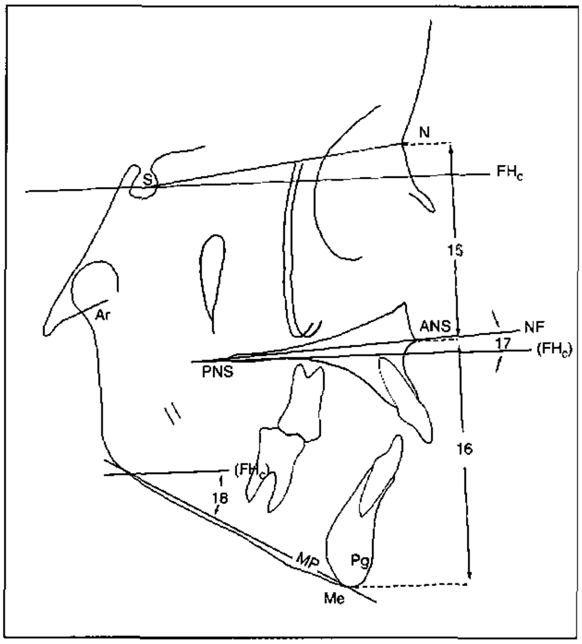


Maxilla and Mandible (*cont.*)



9. **Ar-Pg (FH_C):** Articulare to pogonion, measured parallel to the FH_C. This is an "effective" mandibular length measurement since it is measured parallel to the FH_C. In some individuals the mandibular body length may be very long but of only average length relative to the FH_C, due to a steep mandibular plane angle. In other words, although the mandibular body length in these individuals is very long, its "effective length" is average.
10. **Ar-Pg:** Articulare to pogonion, the direct measurement of the mandibular length. Other things being equal, longer mandibles are found in Class III or prognathic skeletal relationships, and vice-versa.
11. **Ar-Go:** Articulare to gonion. This is a direct measurement of the ramal length. Other things being equal, the shorter this length, the greater the likelihood of finding a Class II or a retrognathism; the longer this length, the greater the likelihood of finding a Class III or a prognathism.
12. **Go-Pg:** Gonion to pogonion. This is a direct measurement of the mandibular body, or corpus, length. The length of the body of the mandible is usually about 1.7 times the length of the ramus. The longer this measurement, the greater the likelihood of finding a prognathic skeletal profile, and vice-versa.
13. **B-Pg (MP):** Point B to pogonion, measured parallel to the mandibular plane. This is a direct measurement of the length of the hard tissue chin button. In some individuals, a prognathic or Class III skeletal profile could be due to a large hard tissue chin button while the occlusion remains orthognathic.
14. **Ar-Go-Me:** Articulare-gonion-menton, also called the gonial angle. This angular measurement is formed by the intersection of the ramal plane (line) and the mandibular plane (line) and averages about 131 degrees. If the gonial angle is greater than average, one can usually observe an increase in the mandibular plane angle, increased facial convexity, increased retrognathism, and an increased severity to the Class II malocclusion. The vertical height of the face would also tend to be longer than average. Conversely, if the gonial angle is less than average, one usually observes the mandibular plane angle being less than average or "flatter," a flat or concave facial profile, increased facial prognathism, and an increased severity to the Class III malocclusion. To a certain extent, then, the gonial angle determines the type of occlusion one observes.

Facial Height



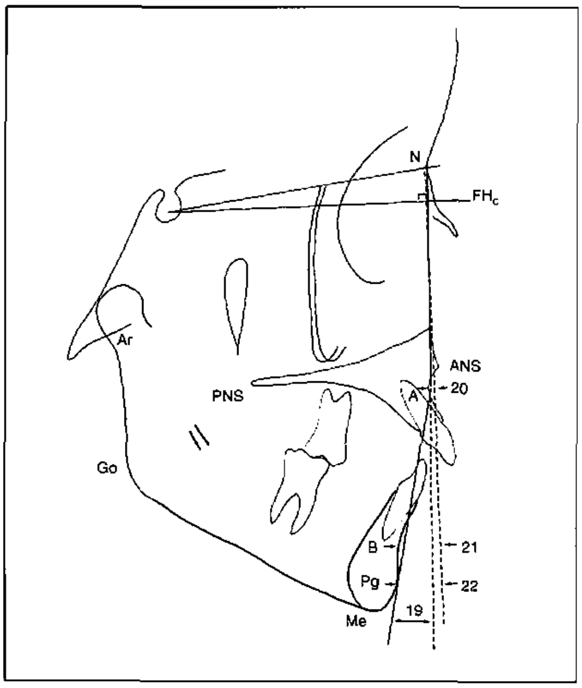
15. N-ANS (pFH$_c$): Nasion to anterior nasal spine, measured perpendicular to the FH$_c$ line. This is a measurement of the middle third of the facial skeleton. In patients with a long or short face, the discrepancy is often due to an excessive or deficient height in the middle third rather than in the lower third of the face. This measurement examines one of the height components of the face.

16. ANS-Me (pFH$_c$): Anterior nasal spine to menton, measured perpendicular to the FH$_c$ line. This measures the lower facial height of a patient, another height component of the face.

17. NF-FH$_c$: Nasal floor relative to Frankfort horizontal. This is the angular orientation of the maxilla (PNS-ANS) relative to the FH$_c$. Measurements made clockwise from FH$_c$ are positive, whereas those made counterclockwise are negative. Negative values are often found in skeletal open bites.

18. MP-FH$_c$: Mandibular plane angle relative to the FH$_c$. This is the angular relationship of the inferior border of the mandible relative to the FH$_c$. Larger than average values are often seen in long-faced patients and vice versa.

Facial Profile



19. N-A-Pg: Nasion to point A to pogonion. If one connects nasion, point A, and pogonion, the angle of hard tissue facial convexity is formed (as the difference from 180 degrees). Normally, the angle of facial convexity is slightly convex (positive angle); if the angle formed is concave or if pogonion is to the right of point A, the angle becomes negative and a Class III skeletal pattern is likely to be present. In any cephalometric analysis, a good starting point would be to describe why the angle of facial convexity is convex, flat, or concave or why the occlusion is Class II or Class III. Since most malocclusions are skeletal in origin, one can find the answers in the size, position, and/or angular orientation of the skeletal components of the occlusion.

20. N-A (FH$_c$): Point A relative to nasion, measured parallel to FHc. This measurement assesses the sagittal or A-P position of the maxilla relative to Nasion. If Point A is to the right of Nasion, the measurement is positive; if to the left, negative.

21. N-B (FH$_c$): Point B relative to nasion, measured parallel to FH$_c$. This is a measurement of the sagittal or A-P position of point B relative to nasion. If point B is to the right of nasion, the measurement is positive; if to the left, negative.

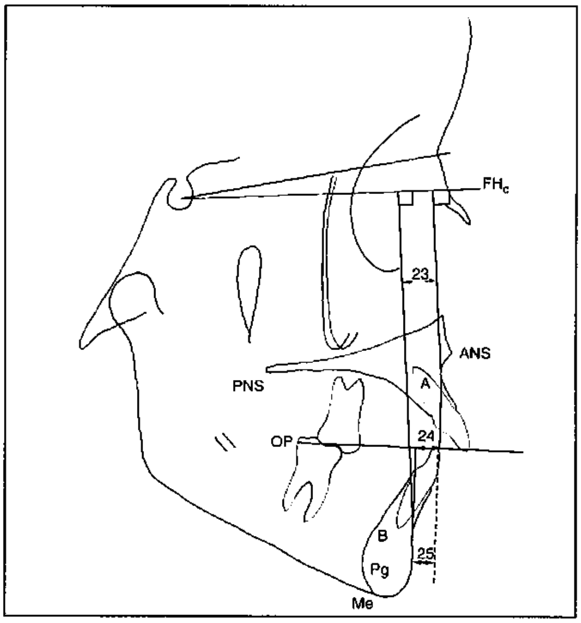
22. N-Pg (FH$_c$): Nasion to pogonion, measured parallel to FH$_c$. This is the sagittal or A-P position of pogonion, the anteriormost point on the mandible, relative to nasion.

Facial Profile (*cont.*)

23. A-B (FH_C): Point A to point B, measured parallel to the FH_C. This is a measurement of the skeletal relationship of the mandible to the maxilla (reference line is skeletal) and is also called the intermaxillary relationship of the maxilla to the mandible.

24. A-B (OP): Point A to point B measured parallel to the occlusal plane. This is also called the denture base relationship since points A and B are compared to a dental reference plane (line)—that is, the occlusal plane. In normal occlusion, the upper denture base is found directly over the lower denture base, ie, A-B(OP) = 0.0 mm.

25. A-Pg (OP): Point A to pogonion, measured parallel to the occlusal plane. This measurement is sometimes used in lieu of the denture base measurement if point B is difficult to find. It is also useful when much root movement has possibly influenced the points A and B.

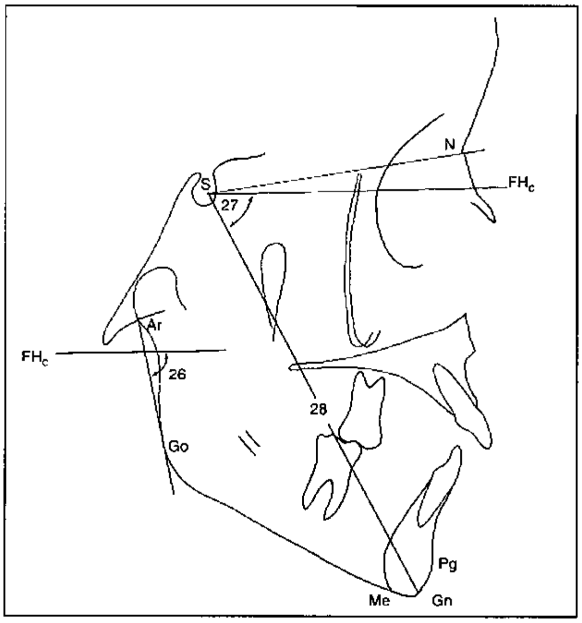


Facial Profile (*cont.*)

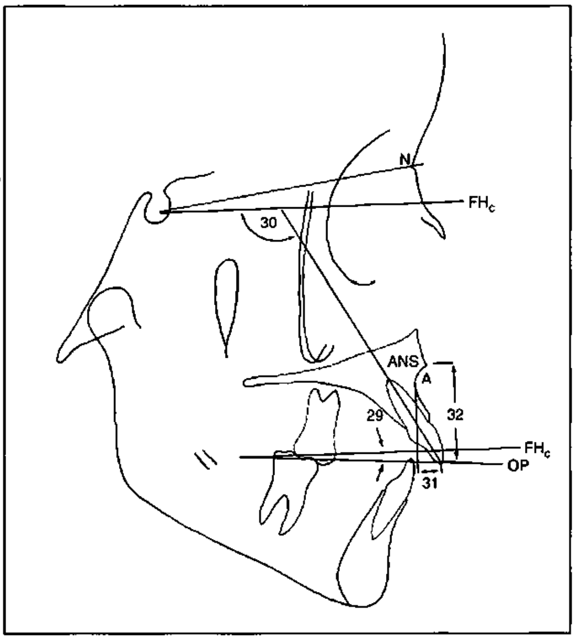
26. Ar-Go (FH_C): Articulare to gonion in relation to the FH_C line. This is called the ramal plane angle and averages about 80 to 90 degrees depending on the age and gender of the patient. Other things being equal, the more obtuse this angle, the greater the tendency to have a Class II or retrognathic profile, and vice-versa.

27. Y-axis-FH_C: The Y-axis is a line that connects sella and gnathion, the anteriormost and inferiormost point on the mandibular symphysis. Gnathion supposedly follows the Y-axis in its descent during growth. Patients with small Y-axis angles tend to be "forward" growers, whereas those with large Y-axis angles tend to be "backward" growers.

28. Y-axis: The absolute length of the Y-axis gives some indication of the size of the mandible, almost like the articulare to pogonion measurement. Long Y-axis lengths are found in Class III or prognathic patients, whereas shorter Y-axis lengths are seen in Class II or retrognathic patients.

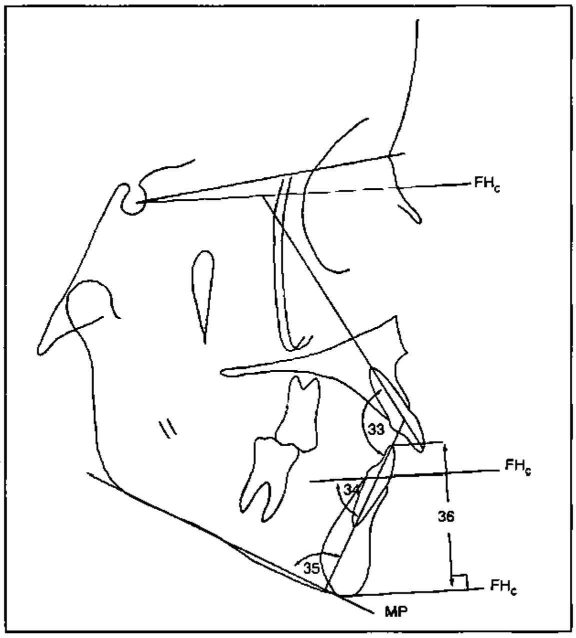


Dental



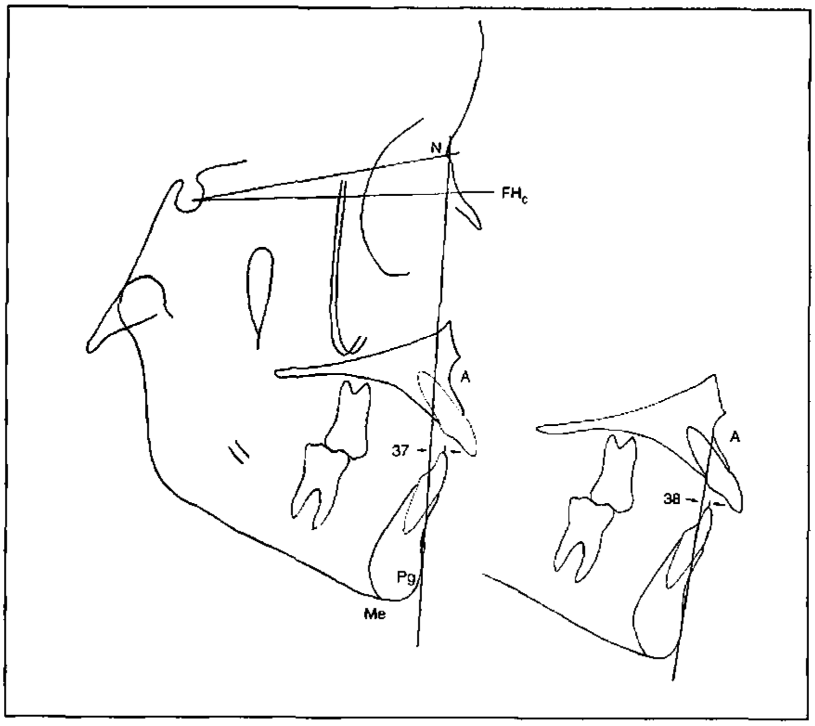
29. **OP-FH_c:** Cant of the occlusal plane relative to the FH_c. This measures the angular relationship of the occlusal plane (line) to the constructed Frankfort horizontal line. The occlusal plane used for these standards bisects the incisal and molar overbite.
30. **$\underline{1}$-FH_c:** Upper central incisor to FH_c line, also called the axial inclination of the upper incisor relative to the FH_c line. Typically, the axial inclination of the upper incisor to the FH_c is about 110 degrees depending on the age and gender of the individual.
31. **$\underline{1}$-A (FH_c):** Upper incisor to point A, measured parallel to the FH_c line. This measurement gives an indication of the anteroposterior position of the upper dentition in relation to the maxillary basal bone.
32. **$\underline{1}$-ANS (pFH_c):** Upper incisor to the anterior nasal spine, measured perpendicular to the FH_c line. This vertical measurement, also called the upper dental height, is one component of the lower facial height.

Dental *(cont.)*



33. **$\underline{1}$-$\overline{1}$:** The interincisal angle or angular relationship of the upper incisor to the lower incisor.
34. **$\overline{1}$-FH_c:** The angular relationship of the lower central incisor to the FH_c line. This is a measurement of the axial inclination of the lower incisor, measured to the FH_c line, and is typically about 60 degrees depending on the age and gender of the patient.
35. **$\overline{1}$-MP:** Lower incisor to the mandibular plane angle. This angle tends to be about 90 to 95 degrees depending on the age and gender of the patient.
36. **$\overline{1}$-Me (pFH_c):** Lower incisor to menton, measured perpendicular to the FH_c line. This is a measurement of the lower dental height, another component of the lower facial height.

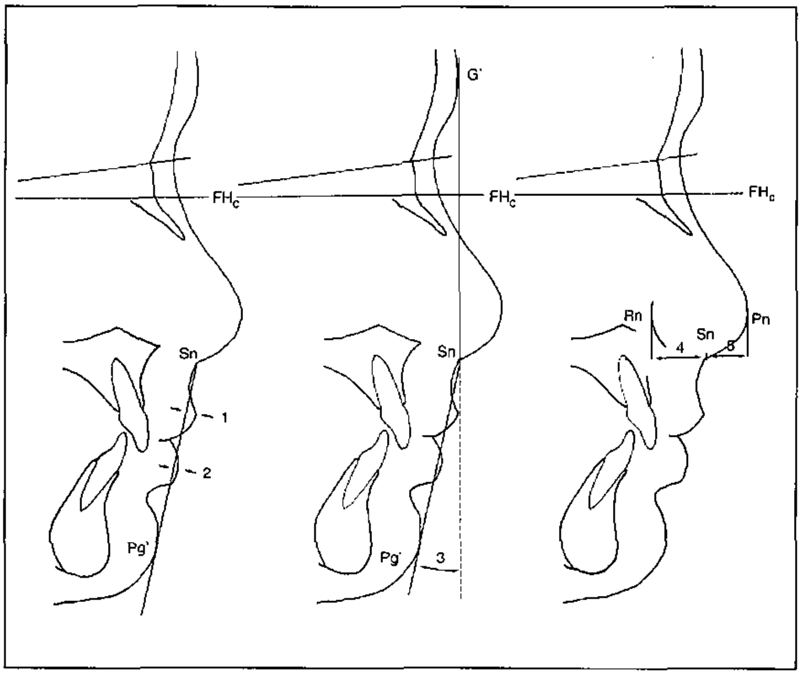
Dental (*cont.*)



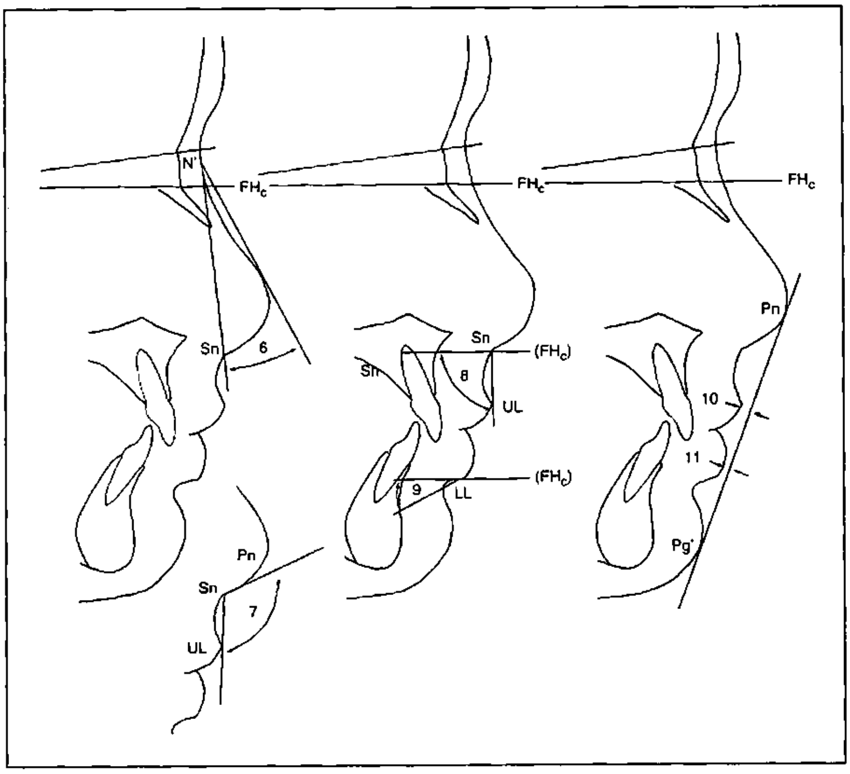
37. $\bar{1}$-N-Pg: Anteroposterior position of the lower incisor relative to a line from nasion to pogonion (the facial plane). The lower incisors are typically found about 3.0 mm anterior to the facial plane.

38. $\bar{1}$-A-Pg: The anteroposterior position of the lower incisor relative to a line from point A to pogonion (the denture plane). This is another measurement of the sagittal or anteroposterior position of the lower incisor; typically, during the teenage years, the lower incisors are found about 2 mm anterior to the denture plane.

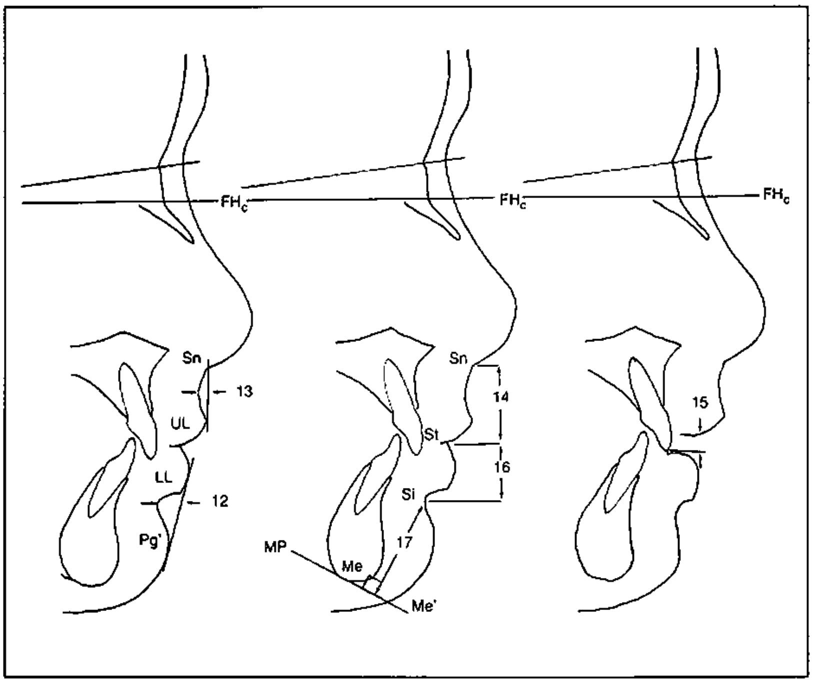
Soft Tissue Cephalometric Measurements



1. **UL (Sn-Pg):** Upper lip to subnasale–soft tissue pogonion line. This a measurement of the upper lip protrusion relative to the base of the nose and tip of the soft tissue chin (Pg'). This measurement of upper and lower lip protrusion should be made with the lips lightly touching; it is usually done clinically with a length of dental floss or wire ligature connecting, in profile, the points subnasale and soft tissue pogonion.
2. **LL (Sn-Pg'):** Lower lip to subnasale–soft tissue pogonion line. This a measurement of the lower lip protrusion relative to the base of the nose (Sn) and tip of the soft tissue chin (Pg'). Like the upper lip protrusion, this measurement of the lower lip protrusion should be made with the lips lightly touching, not at rest. (Sometimes resting lips do make contact; this is fine as long as the observer can distinguish when the contacting lips are at rest.)
3. **G'-Sn-Pg':** A measurement of the soft tissue facial convexity or concavity, connecting soft tissue glabella, subnasale, and soft tissue pogonion. Similar to the angle of hard tissue facial convexity, a line drawn from glabella (G') to subnasale (Sn) is extended; another line drawn from subnasale to soft tissue pogonion (Pg') forms a small angle at subnasale. This is the angle of soft tissue facial convexity. If Pg' is to the right of the original extended line, then the angle formed at Sn will be the angle of soft tissue concavity and will be negative (counterclockwise) from the straight line.
4. **Rn-Sn:** Retronasale to subnasale, measured parallel to the FH$_C$ line. This is a measurement of the posterior extent of the nose which, together with the anterior extent of the nose, makes up the total sagittal dimension of the nose.
5. **Sn-Pn:** Subnasale to pronasale, measured parallel to the FH$_C$ line. This is a measurement of the anterior extent of the nose which, together with the posterior extent, makes up the total sagittal dimension of the nose.



6. **Sn-N'-Pn:** Subnasale to soft tissue nasion to pronasale, also called the nasal angle. This angular measurement is also another measure of the size of the anterior extent of the nose. Other things being equal, a larger angle would mean a larger anterior nose, and vice-versa; however, angular measurements are dangerous to use for length or distance measurements.
7. **Pn-Sn-UL:** Pronasale to subnasale to upper lip, also called the nasolabial angle. This angle is often increased by the orthodontic retraction of the upper incisors, producing what has been termed the "orthodontic look," a posttreatment increase in the nasolabial angle. In those patients whose nasolabial angles are more obtuse than average, incisor retraction is contraindicated.
8. **Subnasale to UL:** Upper lip inclination. The line from subnasale to the anteriormost point on the upper lip and Frankfort horizontal forms an angle indicating the resting inclination of the upper lip.
9. **Mandibular sulcus to LL:** Lower lip inclination. The line from the mandibular sulcus to the anteriormost point on the lower lip and Frankfort horizontal forms an angle indicating the resting inclination of the lower lip.
10. **Upper lip to esthetic plane:** The esthetic plane (line) is formed from the tip of the nose to the tip of the soft tissue chin and is used by some practitioners to measure lip protrusion.
11. **Lower lip to esthetic plane:** The esthetic plane (line) is formed by connecting the tip of the nose and the tip of the soft tissue chin; the protrusion of the lower lip is measured to this line. The size of the nose can greatly influence the protrusion of the lips; thus, a person with a large nose will have very retrusive lips when compared to the esthetic plane, whereas a person with a small nose would have very protrusive lips compared to the esthetic plane. This is a drawback when using this plane (line) to measure lip protrusion.



12. **Si:** Mandibular sulcus. The mandibular sulcus is measured as the maximum depth from a line connecting soft tissue pogonion and the lower lip (LL).
13. **Ss:** Maxillary sulcus. The maxillary sulcus is measured as the maximum depth from a line connecting subnasale to the upper lip (UL).
14. **Sn-Stm:** Subnasale to stomion, measured perpendicular to the FH_c line. This is a vertical measurement of the upper lip length, from subnasale to the juncture between the contacting lips. Normally, lip-length measurements are made when the lips are resting, and an interlabial gap may or may not be present. When an interlabial gap is present, there is an "upper-lip stomion" the inferiormost point of the upper lip, and a "lower-lip stomion," the superiormost point of the lower lip.
15. **UL-Is:** Upper lip to incision stomion. This is a measurement of the amount of incisor visible when the lips are at rest. Sometimes lips are contacting when they are at rest.
16. **Si-Stm (pFH_c):** Mandibular sulcus to stomion, measured perpendicular to the constructed Frankfort horizontal line. This is a measurement of the lower lip length. When the lips are in contact, stomion is found at the point of juncture of both lips.
17. **Me'-Si (pMP):** Soft tissue menton to mandibular sulcus, measured perpendicular to the mandibular plane, is a measurement of the height of the soft tissue chin.

(continued on page 251)

Table B-1 Longitudinal Cephalometric Data—Absolute (Female)*

DA	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5
P + yrs		–7	–6	–5	–4	–3	–2	–1	P	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
Cranial base																			
1. N-Ar (FH_c)	73.0	73.2	74.3	75.6	76.7	77.7	78.8	79.8	81.3	82.2	82.6	82.8	83.0	83.2	83.4	83.0	83.1	83.2	82.8
	4.16	2.80	3.27	3.38	3.40	3.28	3.27	3.5	3.51	3.55	3.82	3.73	3.81	3.68	3.61	3.12	3.30	2.88	1.77
2. N-Ba (FH_c)	81.3	81.7	82.1	83.3	84.6	85.7	87.0	88.1	89.4	90.6	91.1	91.3	91.4	91.6	91.8	91.0	91.3	90.6	93.5
	6.67	5.28	4.68	4.64	5.21	5.25	5.01	5.29	4.24	5.45	5.50	5.60	5.61	5.56	5.47	3.86	3.93	3.80	4.99
3. Ar-Ptm (FH_c)	28.8	29.1	29.5	30.1	30.5	30.8	31.2	31.5	32.1	32.5	32.6	32.7	32.8	32.8	32.8	32.5	32.5	32.3	32.3
	2.04	2.68	2.43	2.38	2.26	2.16	2.14	2.27	2.20	2.05	2.11	2.13	1.97	1.91	1.90	1.92	1.63	1.54	1.06
4. S-N	61.1	61.8	62.5	63.4	64.0	64.7	65.6	66.2	67.2	67.8	68.3	68.4	68.5	68.7	68.8	68.3	69.2	69.3	70.5
	3.87	3.27	2.96	3.12	3.25	3.27	3.49	3.42	3.43	3.65	3.78	3.78	3.76	3.61	3.55	2.90	3.10	3.71	7.78
5. S-Ar	26.3	26.8	27.2	27.9	28.6	29.0	29.5	30.5	30.9	31.3	31.6	31.7	31.9	31.9	31.8	31.9	32.0	32.2	31.3
	1.63	1.78	1.76	1.73	1.78	1.69	1.64	1.88	1.74	1.80	1.97	1.99	2.19	2.12	2.17	2.24	2.05	2.38	0.35
6. N-S-Ar (°)	124.7	123.1	123.9	124.2	124.9	124.1	124.6	124.8	125.3	125.6	125.3	125.4	125.4	125.6	125.9	125.8	124.6	124.7	125.0
	3.79	4.18	3.91	4.44	4.69	4.41	4.10	4.12	4.37	4.81	4.40	4.28	4.24	4.65	4.52	4.65	4.80	4.50	8.49
Maxilla and mandible																			
7. PNS-ANS (FH_c)	44.8	45.0	45.7	46.7	47.4	48.0	49.0	50.1	51.3	51.9	52.2	54.4	52.5	52.6	52.7	52.7	53.6	54.9	58.0
	1.21	2.44	2.24	2.41	3.48	2.30	2.70	2.71	2.74	2.66	3.11	3.25	3.30	3.47	3.47	3.56	3.85	3.54	4.24
8. PNS-A (FH_c)	41.3	41.9	42.0	42.7	43.2	43.8	44.8	45.9	46.9	47.4	47.7	48.0	48.3	48.3	48.4	48.6	49.5	50.5	53.0
	1.03	2.38	1.97	1.99	2.03	1.91	2.04	2.23	2.45	2.40	2.63	2.72	2.96	2.87	2.90	3.00	3.14	2.72	2.83
9. Ar-Pg (FH_c)	62.3	62.7	62.4	64.2	65.5	67.1	68.7	70.3	73.1	74.6	75.6	76.0	76.8	76.7	76.8	76.5	76.1	76.6	80.0
	5.29	5.25	4.76	5.29	5.01	5.13	5.33	5.76	5.91	5.87	5.97	6.04	6.15	5.60	5.81	5.80	6.15	5.33	8.49
10. Ar-Pg	84.3	84.5	86.0	88.2	90.3	92.1	94.3	96.3	99.8	101.7	103.1	103.7	104.4	104.7	104.9	104.3	105.0	105.3	107.3
	5.42	4.57	4.37	4.17	4.29	4.25	4.27	4.43	4.51	4.14	4.39	4.60	4.67	4.60	4.52	3.61	3.97	4.20	8.13
11. Ar-Go	34.7	35.0	35.5	36.6	37.5	38.3	39.3	40.5	42.7	44.0	44.9	45.9	46.4	46.8	47.0	47.3	47.5	47.7	50.8
	1.83	1.81	1.86	2.09	1.71	1.86	1.92	2.07	2.41	2.04	2.10	2.43	2.29	2.51	2.66	2.51	3.17	3.01	1.06
12. Go-Pg	61.3	60.6	62.3	63.4	65.2	66.4	68.2	69.4	71.3	72.5	73.3	73.7	74.1	74.3	74.4	73.4	73.1	74.4	75.5
	5.60	6.56	5.40	5.32	5.85	5.40	5.06	5.17	5.83	5.94	6.12	6.00	5.92	5.81	5.79	4.26	5.40	3.04	4.24
13. B-Pg (MP)	3.9	3.9	4.0	4.5	4.8	5.3	6.0	6.0	6.4	6.7	6.9	7.0	7.1	7.2	7.3	7.0	7.2	7.0	7.5
	2.06	1.84	1.83	1.75	1.70	1.60	1.72	1.73	1.83	1.90	1.84	1.93	1.93	1.91	1.93	1.23	1.31	1.10	2.12
14. Ar-Go-Gn (°)	123.6	125.6	125.0	125.1	124.8	124.5	124.0	123.9	123.9	123.4	123.1	122.5	122.1	122.0	122.3	122.5	123.9	121.1	118.3
	4.79	7.00	6.35	6.31	6.61	6.67	6.43	6.54	6.64	6.68	6.96	6.84	6.86	7.07	7.19	7.19	7.68	5.63	6.72

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-1 Longitudinal Cephalometric Data—Absolute (Female) *(continued)**

DA	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5
P + yrs		–7	–6	–5	–4	–3	–2	–1	P	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
Facial height																			
15. N-ANS (pFH_c)	39.4	40.5	41.9	43.2	44.6	45.5	46.7	47.7	48.5	49.2	49.5	49.8	49.8	50.0	50.1	49.7	50.8	50.9	52.0
	3.57	2.25	2.42	2.26	2.38	2.16	2.31	2.46	2.31	2.26	2.46	2.36	2.38	2.41	2.48	2.38	2.25	1.43	1.41
16. ANS-Me (pFH_c)	51.0	51.5	52.5	52.9	53.6	54.7	55.4	56.7	58.1	59.4	60.4	60.8	61.1	61.3	61.5	61.3	62.3	62.2	59.8
	2.07	2.24	2.00	2.25	2.47	2.86	2.96	3.28	3.46	3.32	3.49	3.43	3.39	3.32	3.40	3.41	3.36	3.70	3.89
17. NF-FH_c (°)	–1.4	–0.6	–0.3	0.2	0.1	0.0	0.4	0.8	0.6	0.6	0.5	0.6	0.7	0.6	0.7	0.6	0.8	0.1	2.3
	3.48	2.97	2.69	2.61	2.74	2.77	2.79	3.07	5.12	3.07	3.15	3.08	3.07	3.13	3.23	3.09	3.00	3.34	3.18
18. MP-FH_c (°)	25.0	26.1	27.5	26.9	27.0	26.8	26.7	26.1	25.5	25.2	24.8	24.6	24.1	24.2	24.4	24.0	25.2	23.8	20.0
	5.41	4.99	4.59	4.92	4.47	4.49	4.89	4.88	5.17	5.10	5.06	4.99	5.19	4.97	5.39	5.14	4.81	3.82	1.41
Facial profile																			
19. N-A-Pg (°)	6.8	7.4	8.1	7.0	6.8	5.9	5.9	5.6	4.5	3.6	2.9	2.7	2.5	2.6	2.3	2.9	4.9	5.8	6.3
	4.25	3.20	4.71	4.59	4.35	3.96	4.16	4.35	4.87	5.03	5.29	5.15	5.32	5.08	5.33	4.72	5.21	4.26	4.60
20. N-A (FH_c)	–2.8	–2.2	–2.8	–2.6	–2.6	–2.6	–2.4	–2.1	–2.2	–2.2	–2.3	–2.2	–1.9	–2.0	–2.3	–2.0	–1.5	–0.8	0.5
	3.37	3.38	3.07	3.23	3.57	3.60	3.36	3.57	3.63	3.83	3.71	3.75	3.87	3.74	3.70	3.51	3.81	2.42	0.71
21. N-B (FH_c)	–9.0	–8.9	–9.9	–9.9	–10.0	–9.4	–9.2	–8.8	–7.9	–7.6	–7.2	–7.0	–6.7	–6.9	–7.1	–6.9	–7.3	–7.2	–6.5
	6.07	4.85	4.07	4.21	4.15	4.21	3.88	4.18	4.40	4.50	4.04	4.24	4.45	4.29	4.25	4.11	3.60	2.27	4.24
22. N-Pg (FH_c)	–10.7	–10.7	–11.8	–11.2	–11.0	–10.4	–10.1	–9.4	–8.3	–7.7	–7.0	–6.8	–6.2	–6.5	–6.6	–6.5	–7.4	–7.1	–4.8
	6.55	5.33	4.86	4.84	4.55	4.96	4.66	5.10	5.42	5.59	5.09	5.31	5.60	5.12	5.19	5.28	4.86	3.15	5.30
23. A-B (FH_c)	–6.2	–6.7	–7.1	–7.3	–7.3	–6.8	–6.8	–6.6	–5.7	–5.4	–4.9	–4.	–4.8	–4.9	4.8	–4.8	–5.8	–6.4	–7.0
	3.31	2.56	2.31	2.98	2.55	2.63	2.50	2.93	2.65	2.62	2.12	2.34	2.37	2.31	2.34	2.42	2.21	2.22	3.53
24. A-B (OP)	–1.2	–0.5	–0.5	–0.8	–0.7	–0.1	–0.6	–0.6	–0.3	–0.5	–0.3	–0.5	–0.3	–0.4	–0.5	–0.3	–1.1	–2.1	–1.5
	2.40	1.99	1.90	1.87	1.73	1.56	1.97	2.54	2.52	2.59	2.51	2.50	2.60	2.54	2.67	2.95	3.11	3.01	4.24
25. A-Pg (OP)	0.3	0.1	0.4	0.4	1.0	1.6	1.4	1.3	2.0	2.0	2.2	2.2	2.3	2.3	2.2	1.9	1.3	0.3	3.0
	3.50	2.64	3.82	2.93	2.92	2.78	3.27	3.47	3.68	3.80	3.91	3.98	4.20	3.91	4.10	3.89	4.40	1.18	6.36
26. Ar-Go -FH_c (°)	81.8	80.5	82.5	81.9	82.3	82.4	82.6	82.3	81.6	81.7	81.7	82.0	82.1	82.1	82.2	81.5	81.3	82.7	81.8
	4.41	5.00	4.14	4.49	4.48	4.36	3.77	4.40	4.40	4.53	5.01	4.88	4.77	5.08	5.07	4.50	4.55	4.60	5.30
27. Y-axis-FH_c (°)	60.0	60.2	61.1	61.0	61.3	60.9	60.9	60.8	60.3	60.3	60.1	60.3	59.9	60.1	60.2	60.2	60.8	60.5	58.8
	3.52	2.93	2.75	2.22	2.82	2.90	2.99	2.83	3.12	3.25	2.98	2.86	3.02	2.73	3.17	2.97	2.81	2.53	3.89
28. Y-axis (mm)	95.2	96.4	98.0	100.5	102.7	105.0	107.1	109.6	112.6	114.7	116.2	116.9	117.4	117.7	117.9	117.5	119.0	119.5	120.3
	4.94	5.60	4.43	4.30	4.93	4.73	4.84	4.94	5.03	4.93	4.29	4.97	4.95	4.94	4.99	4.66	4.76	5.11	10.96

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-1 Longitudinal Cephalometric Data—Absolute (Female) *(continued)**

DA	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5
P + yrs	−7	−6	−5	−4	−3	−2	−1	P	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	
Dental																			
29. OP-FH_c (°)	10.6	11.1	11.7	10.8	11.3	11.2	10.5	9.8	8.9	8.0	7.4	7.2	7.0	7.1	7.2	7.0	7.4	6.8	9.0
	3.48	2.92	3.11	2.71	2.36	2.47	2.52	3.10	2.65	2.41	2.57	2.60	2.60	2.51	2.65	2.80	2.80	2.99	1.41
30. $\underline{1}$-FH_c (°)	99.0	98.0	106.7	110.2	110.0	110.0	109.6	110.3	110.5	111.4	112.2	112.5	112.8	112.5	112.4	113.0	111.8	111.8	104.3
	5.70	7.15	7.31	7.65	7.94	7.61	6.61	7.03	7.20	6.94	6.81	6.99	7.06	7.03	7.27	7.22	7.47	8.31	1.77
31. $\underline{1}$-A (FH_c)	0.0	0.0	0.6	1.5	2.2	3.0	3.0	3.3	3.7	4.1	4.4	4.6	4.5	4.5	4.5	4.6	4.3	4.2	1.3
	1.82	1.90	1.80	2.00	2.19	1.79	1.81	1.97	2.31	2.29	2.26	2.13	2.11	2.17	2.28	2.46	2.47	2.28	1.76
32. $\underline{1}$-ANS (pFH_c)	21.3	21.7	22.4	23.0	24.0	24.8	25.1	25.6	26.0	26.3	26.6	26.6	26.8	26.9	27.0	26.9	27.6	27.9	26.8
	2.94	1.78	2.40	2.07	1.86	1.65	1.73	1.70	1.82	1.68	1.73	1.73	1.76	1.76	1.77	1.85	1.86	1.46	1.77
33. $\underline{1}$-$\overline{1}$ (°)	147.4	148.5	134.6	129.7	126.9	127.9	128.3	128.4	128.5	127.9	127.1	127.3	127.3	127.5	127.4	126.6	126.9	126.3	134.3
	8.53	9.60	6.60	9.72	9.86	8.82	7.95	8.82	8.34	8.90	7.93	7.99	8.32	8.44	8.96	8.74	9.44	8.58	9.55
34. $\overline{1}$-FHc(°)	66.5	66.8	62.1	59.9	58.9	57.8	57.9	58.5	59.9	59.3	59.4	59.8	60.1	60.0	59.8	59.6	58.7	58.0	58.5
	9.13	7.13	4.72	4.50	4.62	4.68	4.58	4.36	4.70	4.30	4.30	4.33	4.48	4.26	4.23	4.34	4.38	4.46	4.78
35. $\overline{1}$-MP (°)	88.5	87.5	90.4	93.2	94.2	95.5	95.5	95.1	95.5	95.5	95.9	95.7	95.9	95.9	95.9	96.4	96.0	98.2	101.5
	5.67	6.86	7.33	6.95	6.63	6.44	5.88	5.99	6.01	5.45	5.66	5.02	5.81	5.74	5.15	5.15	6.32	5.82	9.19
36. $\overline{1}$-Me (pFH_c)	29.5	30.7	31.1	31.6	32.2	33.0	33.9	34.7	35.7	36.3	37.0	37.3	37.4	37.5	37.5	37.5	38.3	37.8	36.5
	1.82	1.49	1.53	1.40	1.58	1.83	1.73	1.64	1.60	1.64	1.71	1.74	1.79	1.78	1.77	1.88	1.59	1.41	0.70
37. $\overline{1}$-(N-Pg)	0.9	2.0	2.5	2.7	3.2	3.3	3.3	3.4	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.5	4.1	4.4	2.5
	1.74	1.96	1.94	2.18	2.25	2.37	2.51	2.60	2.86	2.96	3.13	3.09	3.29	3.19	3.27	3.84	3.14	2.63	3.54
38. $\overline{1}$-(A-Pg)	−0.1	0.3	0.6	1.1	1.5	1.8	1.7	1.8	2.1	2.3	2.5	2.5	2.5	2.5	2.5	2.7	2.6	2.4	0.8
	1.28	0.92	1.27	1.78	1.98	1.75	1.95	2.02	2.21	2.06	2.16	2.10	2.30	2.30	2.40	2.32	2.71	2.80	2.47

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-2 Longitudinal Cephalometric Data—Absolute (Male)*

DA	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0
P + yrs		−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	P	+1	+2	+3	+4	+5	+6	+7
Cranial base																			
1. N-Ar (FH_c)	74.7	76.7	76.7	77.6	78.8	80.3	81.8	82.7	83.7	84.8	86.3	87.9	88.8	89.5	89.7	90.0	90.0	90.1	89.2
	5.51	4.42	4.02	4.23	4.25	4.47	4.32	4.36	4.38	4.72	4.81	4.79	4.68	5.14	4.99	5.02	4.00	4.48	4.37
2. N-Ba (FH_c)	82.5	85.0	85.1	86.2	87.3	88.7	90.0	90.9	92.3	93.1	94.5	96.0	97.1	97.8	98.0	98.2	98.6	98.6	97.2
	6.50	4.44	5.39	5.24	5.29	5.47	5.20	5.36	5.60	5.56	5.48	5.59	5.39	5.70	5.64	5.55	4.79	5.62	3.75
3. Ar-Ptm(FH_c)	29.2	30.2	30.6	31.1	31.9	32.7	33.6	34.1	34.4	35.0	35.6	36.2	36.9	37.1	37.1	37.1	37.5	37.6	36.5
	1.26	2.36	2.01	2.12	2.27	2.54	2.59	2.67	2.64	2.69	2.77	2.76	2.96	2.84	2.89	2.93	2.50	2.73	3.28
4. S-N	64.3	64.3	64.5	65.3	66.5	67.1	67.8	68.6	69.3	69.6	70.6	71.8	72.7	73.4	73.7	73.9	73.7	74.4	74.7
	5.80	4.03	3.15	3.33	3.36	3.37	3.48	3.37	3.71	3.63	3.24	3.29	3.16	3.37	3.50	3.45	2.36	2.40	1.89
5. S-Ar	27.0	28.1	28.6	29.2	29.7	30.7	31.5	32.3	33.0	33.8	34.4	35.4	35.9	36.3	36.6	36.7	36.5	35.9	34.0
	1.80	1.28	1.33	1.76	2.00	2.07	1.86	2.29	1.92	1.99	2.06	2.39	2.29	2.26	2.26	2.28	2.55	2.56	1.80
6. N-S-Ar (°)	123.0	125.2	124.8	124.9	124.4	125.2	125.5	125.5	125.6	125.9	126.0	126.0	125.5	125.4	125.3	125.4	126.2	125.4	124.8
	5.29	6.74	5.39	5.02	5.13	5.07	4.99	5.04	4.72	5.31	5.01	5.25	4.90	5.42	4.85	4.90	5.10	5.46	5.97
Maxilla and mandible																			
7. PNS-ANS (FH_c)	47.0	48.3	48.8	49.4	49.8	50.8	51.8	52.5	53.0	54.1	55.1	56.5	57.3	57.7	58.0	58.1	58.2	58.6	57.7
	4.00	3.63	2.84	2.53	2.43	2.64	2.64	2.48	2.53	2.30	2.75	2.58	2.52	2.49	2.44	2.48	2.59	2.32	0.76
8. PNS-A (FH_c)	42.0	44.1	44.3	44.8	44.7	45.5	46.0	46.9	47.6	48.6	49.8	51.0	51.7	52.4	52.6	52.8	53.0	53.2	51.2
	1.00	2.99	2.21	2.03	2.00	1.77	1.74	1.86	2.09	1.95	1.85	1.61	1.61	2.04	2.01	1.95	2.08	2.24	0.76
9. Ar-Pg (FH_c)	63.7	65.1	65.7	67.7	68.3	70.5	71.9	73.4	74.7	76.7	78.8	81.4	83.4	85.1	86.0	86.7	85.9	85.4	77.3
	1.53	3.11	3.09	3.31	3.92	4.03	4.40	4.57	4.21	4.98	5.16	5.75	6.49	6.90	6.87	6.89	7.49	8.73	8.61
10. Ar-Pg	87.0	89.3	89.9	92.2	93.9	96.3	98.5	100.2	102.1	104.3	107.1	111.8	114.1	116.0	117.0	117.6	118.0	118.1	115.2
	3.12	2.88	3.68	3.44	3.38	3.28	3.27	3.38	2.97	3.32	3.31	3.82	3.63	3.75	3.49	3.41	3.72	3.90	1.61
11. Ar-Go	37.3	37.0	37.1	38.6	39.1	40.1	41.0	41.9	42.8	44.2	45.8	48.8	50.3	52.0	52.7	53.7	53.6	54.1	53.5
	2.02	1.92	2.19	2.17	2.48	2.68	2.61	2.77	2.81	3.30	3.30	3.67	3.75	4.18	4.06	4.14	3.75	2.23	3.28
12. Go-Pg	61.2	62.8	63.7	64.2	66.9	69.0	70.8	72.3	74.0	75.1	77.8	80.4	82.4	83.7	84.2	84.4	84.4	85.2	82.3
	3.33	3.53	3.62	3.42	3.51	3.62	3.40	3.61	3.82	3.34	3.63	4.52	4.31	4.61	4.80	4.93	4.28	3.69	0.58
13. B-Pg (MP)	4.7	4.5	4.8	5.0	5.1	5.7	6.1	6.6	6.8	7.1	7.4	8.1	8.6	8.9	8.9	9.1	9.2	9.1	8.7
	0.29	1.30	1.37	1.31	1.27	1.21	1.28	1.09	0.98	1.16	1.33	1.42	1.56	1.73	1.75	1.81	1.92	2.03	2.08
14. Ar-Go-Gn (°)	127.3	128.8	128.1	126.5	126.1	125.4	124.9	124.4	123.5	123.8	122.6	121.4	120.3	119.1	119.2	118.9	119.5	118.2	116.5
	6.66	5.72	6.45	6.68	5.54	5.30	5.24	5.30	6.10	5.54	5.84	5.87	6.10	6.50	6.99	7.47	6.69	4.54	3.50

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-2 Longitudinal Cephalometric Data—Absolute (Male) *(continued)**

DA	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0
P + yrs	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	P	+1	+2	+3	+4	+5	+6	+7	
Facial height																			
15. N-ANS (pFH_c)	41.8	42.8	43.2	43.9	45.2	46.6	48.0	48.8	49.9	50.6	52.2	53.7	54.2	54.7	54.9	54.9	55.4	55.3	52.5
	2.75	2.58	2.79	3.01	2.52	3.04	3.04	3.00	3.01	3.13	2.97	3.28	3.17	3.19	3.37	3.36	3.55	4.00	4.09
16. ANS-Me (pFH_c)	53.0	54.2	54.4	55.3	56.5	57.2	58.5	59.3	60.5	61.6	63.1	66.0	67.8	68.6	69.3	69.8	70.4	70.5	74.5
	2.65	3.67	3.23	2.94	3.23	3.14	3.15	2.91	2.92	2.98	3.20	3.44	3.59	3.79	4.01	4.11	4.41	5.16	1.80
17. NF-FH_c (°)	0.8	0.8	-0.3	-0.7	-0.3	0.0	0.1	0.1	0.7	0.6	0.8	0.5	0.3	0.0	-0.3	-0.3	0.0	0.1	-0.6
	2.75	2.48	3.31	3.88	3.56	3.64	3.50	3.01	3.53	3.27	2.95	2.83	2.95	3.13	3.30	3.51	3.31	3.81	5.48
18. MP-FH_c (°)	27.0	27.8	27.3	26.6	26.8	26.3	26.3	26.2	25.6	25.3	25.0	24.5	23.9	23.0	22.5	22.1	23.2	22.7	26.2
	6.50	4.64	4.15	3.73	4.18	4.26	4.50	4.33	4.78	4.74	4.45	4.99	5.53	5.93	5.88	5.86	5.22	5.97	7.22
Facial profile																			
19. N-A-Pg (°)	6.3	8.3	9.0	8.1	8.4	7.0	6.4	6.3	6.1	6.5	6.1	5.2	4.5	3.9	3.3	2.6	4.5	5.3	7.2
	3.51	5.91	4.78	4.24	4.64	4.22	4.49	4.67	4.54	5.01	4.89	5.66	6.01	6.37	6.53	6.35	5.53	6.40	8.75
20. N-A (FH_c)	-3.5	-2.3	-1.9	-1.7	-2.0	-2.0	-2.2	-2.0	-1.7	-1.1	-0.9	-0.6	-0.3	0.0	0.0	0.0	0.4	0.8	-1.5
	3.50	3.25	3.11	3.47	3.33	3.08	2.78	3.12	3.07	3.52	3.43	3.31	3.05	3.72	3.83	3.70	3.04	3.68	2.29
21. N-B (FH_c)	-9.2	-8.8	-8.8	-8.4	-9.0	-8.6	-8.9	-8.7	-8.3	-7.6	-7.4	-6.9	-6.0	-5.3	-5.5	-5.4	-5.1	-5.5	-10.8
	4.19	3.53	4.43	4.78	5.06	4.84	4.85	5.01	4.80	5.56	5.69	5.69	5.86	5.73	6.62	6.77	5.89	7.01	7.97
22. N-Pg (FH_c)	-11.2	-11.6	-11.0	-10.1	-10.5	-9.7	-9.9	-9.3	-8.9	-8.1	-7.6	-6.4	-5.3	-4.3	-3.6	-3.3	-4.2	-4.6	-11.8
	5.10	3.58	4.27	5.21	5.28	5.23	5.17	5.75	5.25	5.52	6.60	6.92	7.54	8.47	8.15	8.48	8.48	10.10	12.94
23. A-B (FH_c)	-6.0	-6.5	-6.9	-6.8	-6.9	-6.6	-6.4	-6.7	-6.5	-6.5	-6.5	-6.5	-5.7	-5.3	-5.2	-4.9	-5.5	-6.3	-9.3
	1.32	2.65	2.53	2.33	2.81	2.79	2.87	3.04	2.77	3.13	3.40	3.37	4.22	4.51	4.02	4.13	4.00	4.86	6.60
24. A-B (OP)	0.0	-0.6	-0.5	-0.3	0.0	0.0	0.1	-0.3	-0.4	-0.6	-0.8	-1.1	-1.1	-1.1	-1.0	-0.7	-1.0	-1.1	-0.2
	1.00	3.02	2.39	1.84	1.75	1.69	1.46	1.41	1.64	1.82	1.96	1.92	1.92	1.97	2.27	2.17	1.88	1.90	2.57
25. A-Pg (OP)	0.50	-0.50	0.14	0.98	1.57	1.82	2.29	2.21	1.86	1.75	2.11	1.96	2.30	2.16	2.11	2.64	2.14	1.83	0.83
	0.50	3.07	2.83	2.08	2.14	2.15	1.96	2.21	2.27	2.79	2.75	2.82	2.89	2.76	3.17	3.21	3.59	3.87	5.30
26. Ar-Go-FH_c	79.7	78.9	78.8	79.1	80.8	80.8	81.4	81.7	82.3	81.4	82.5	83.1	83.5	83.8	83.8	83.2	83.8	84.5	89.7
	2.25	4.09	3.63	3.90	3.67	3.77	3.40	3.56	4.11	4.26	4.29	4.42	4.22	5.26	5.54	5.92	6.08	6.48	4.54
27. Y-axis-FH_c (°)	60.2	60.3	60.5	60.1	60.6	60.4	60.6	60.6	60.6	60.6	60.5	60.6	60.1	60.0	59.7	59.6	60.4	60.2	63.2
	1.26	1.29	1.78	1.88	2.12	2.06	2.16	2.30	2.33	2.79	2.67	3.04	3.27	3.61	3.53	3.49	3.48	4.26	5.48
28. Y-axis (mm)	99.5	101.7	102.6	104.7	107.1	109.4	111.7	113.8	116.0	118.2	121.6	126.3	129.2	131.0	132.0	132.6	132.8	133.2	131.5
	3.61	4.17	4.03	3.88	3.71	3.50	3.45	3.53	2.91	3.29	3.96	3.25	3.07	3.10	2.70	2.85	3.25	3.63	1.00

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-2 Longitudinal Cephalometric Data—Absolute (Male) *(continued)**

DA	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0
P + yrs		−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	P	+1	+2	+3	+4	+5	+6	+7
Dental																			
29. OP-FH$_c$ (°)	11.5	10.3	11.0	10.9	11.6	11.2	11.1	10.5	9.9	9.4	8.6	7.5	6.7	6.2	5.4	5.5	6.3	6.5	9.7
	2.18	2.44	3.11	2.11	3.03	3.27	3.18	3.43	3.19	3.17	3.74	4.24	4.47	5.12	4.72	4.84	4.74	5.41	5.51
30. $\underline{1}$-FH$_c$ (°)	105.3	102.4	103.1	104.6	107.4	108.6	109.3	108.7	108.8	109.0	109.0	108.4	108.4	109.0	109.2	109.5	106.4	106.4	103.5
	5.13	7.86	7.04	9.26	5.31	5.34	5.62	6.11	6.57	6.46	6.58	8.34	8.40	9.02	9.24	9.88	9.23	9.15	8.52
31. $\underline{1}$-A (FH$_c$)	−0.3	−0.3	0.1	0.8	1.1	2.3	3.1	3.0	3.2	3.4	3.4	3.5	3.7	3.7	4.0	4.1	3.1	3.2	3.0
	0.58	0.98	1.72	1.46	1.73	1.91	1.94	2.26	2.02	2.19	2.29	2.56	2.93	3.21	3.15	3.36	3.15	3.61	4.36
32. $\underline{1}$-ANS (pFH$_c$)	23.3	23.3	23.5	23.8	24.1	25.8	26.8	27.2	27.6	28.0	28.4	29.0	29.4	29.6	29.8	29.8	30.0	30.5	34.0
	2.25	2.32	2.11	1.92	3.91	2.47	2.61	2.38	2.50	2.57	2.57	2.56	2.84	2.89	2.91	2.88	3.06	3.57	1.73
33. $\underline{1}$-$\overline{1}$ (°)	143.3	144.8	142.0	138.9	133.6	132.5	130.1	129.9	129.7	130.2	130.4	131.1	131.6	132.3	133.1	133.0	135.4	135.0	135.5
	14.15	9.21	9.24	6.10	6.92	4.27	5.64	6.90	7.44	7.44	7.73	8.80	8.66	8.04	10.10	9.88	8.83	10.40	3.12
34. $\overline{1}$-FHc(°)	68.7	67.1	66.2	63.8	61.6	59.7	58.7	57.9	58.5	59.3	59.5	59.5	60.1	61.1	62.2	62.5	61.8	61.4	59.0
	9.29	3.37	5.79	3.55	4.94	4.96	3.61	4.31	4.19	4.47	5.25	5.50	5.27	5.18	5.94	5.81	5.42	6.41	6.00
35. $\overline{1}$-MP (°)	83.3	87.0	87.4	89.5	92.1	94.0	95.0	95.9	95.5	95.4	95.4	95.9	95.9	95.9	95.3	95.4	95.0	95.8	95.0
	8.95	7.40	7.94	5.07	6.90	6.18	4.96	5.16	4.45	5.04	5.04	5.49	5.11	5.71	5.51	5.30	5.41	5.64	3.46
36. $\overline{1}$-Me (pFH$_c$)	30.5	32.1	32.7	33.8	34.3	35.1	35.9	36.5	37.3	38.1	39.4	41.0	42.1	42.8	43.2	43.5	43.9	43.9	44.5
	1.32	1.86	1.70	1.67	1.82	1.71	1.63	1.60	1.92	1.68	1.92	1.79	1.85	1.74	1.84	1.86	1.86	1.87	1.00
37. $\overline{1}$-(N-Pg)	1.3	2.0	1.6	2.6	3.3	3.5	3.9	3.8	3.7	3.8	3.8	3.7	3.6	3.3	3.1	3.0	3.2	3.5	5.0
	1.15	1.70	2.45	2.04	2.44	2.39	2.56	2.44	2.49	2.62	2.56	2.67	2.91	3.08	3.05	3.12	2.95	3.73	3.28
38. $\overline{1}$-(A-Pg)	0.00	0.00	−0.1	0.3	1.0	1.4	1.9	1.9	1.6	1.7	1.9	1.8	2.0	1.9	1.8	2.0	1.5	1.6	2.5
	1.00	1.73	2.19	1.98	2.24	2.18	2.41	1.91	1.96	2.12	1.81	1.99	1.20	2.35	2.17	2.21	1.96	2.42	0.50

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-3 Longitudinal Cephalometric Data—Incremental (Female)*

DA	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0
P + yrs	–7	–6	–5	–4	–3	–2	–1	P	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
Cranial base																		
1. N-Ar (FH_c)	1.25	1.45	1.36	1.09	0.81	1.25	1.09	1.50	0.85	0.43	0.14	0.19	0.20	0.22	0.13	–0.30	0.00	0.00
	0.94	0.80	0.89	0.76	0.75	0.61	0.88	0.63	0.77	0.64	0.38	0.48	0.44	0.52	0.35	0.82	0.00	0.00
2. N-Ba (FH_c)	1.58	1.30	1.18	1.28	1.13	1.31	1.13	1.28	1.18	0.56	0.11	0.16	0.15	0.24	0.21	–0.10	–0.17	0.00
	0.58	1.01	0.72	0.88	0.67	0.66	0.72	0.75	1.07	0.60	0.28	0.22	0.22	0.31	0.36	0.32	0.41	0.00
3. Ar-Ptm(FH_c)	0.50	0.90	0.59	0.45	0.28	0.41	0.31	0.63	0.36	0.14	0.03	0.14	0.01	0.03	–0.13	–0.10	0.08	0.00
	0.63	0.57	0.77	0.43	0.36	0.49	0.40	0.53	0.50	0.29	0.21	0.46	0.32	0.22	0.40	0.32	0.20	0.00
4. S-N	0.92	1.25	0.86	0.59	0.75	0.83	0.63	1.30	0.56	0.47	0.13	0.13	0.16	0.09	0.13	–0.05	0.00	0.00
	0.58	0.42	0.50	0.46	0.52	0.50	0.65	0.41	0.44	0.43	0.29	0.22	0.30	0.20	0.20	0.23	0.16	0.00
5. S-Ar	0.67	0.50	0.68	0.69	0.44	0.50	1.00	0.41	0.41	0.29	0.04	0.22	0.03	–0.06	–0.07	–0.05	0.17	0.00
	0.61	0.47	0.82	0.70	0.48	0.48	0.63	0.55	0.56	0.27	0.13	0.45	0.39	0.17	0.18	0.28	0.40	0.00
6. N-S-Ar (°)	0.17	0.65	0.50	0.72	–0.75	0.50	0.16	0.56	0.24	–0.27	0.08	0.00	0.18	0.31	0.05	–0.20	–0.33	0.00
	0.82	2.21	2.15	1.71	1.29	1.13	1.23	1.33	1.53	1.14	1.13	0.78	0.79	0.72	0.47	1.11	0.82	0.00
Maxilla and mandible																		
7. PNS-ANS (FH_c)	0.67	0.55	0.82	0.75	0.59	1.00	1.09	1.22	0.56	0.31	0.20	0.09	0.16	0.08	0.05	0.05	0.00	0.00
	0.52	0.55	0.67	0.68	0.66	0.91	0.69	1.26	0.62	0.54	0.63	0.20	0.35	0.31	0.14	0.28	0.00	0.00
8. PNS-A (FH_c)	0.58	0.05	0.41	0.48	0.59	1.03	1.09	0.97	0.50	0.34	0.29	0.25	0.06	0.05	0.11	0.15	0.00	0.00
	0.58	0.60	0.89	0.65	0.33	0.50	0.74	1.04	0.71	0.51	0.46	0.53	0.39	0.35	0.21	0.34	0.00	0.00
9. Ar-Pg (FH_c)	1.50	1.20	1.49	1.29	1.59	1.63	1.59	2.78	1.53	1.03	0.38	0.74	–0.06	0.11	–0.02	0.05	0.25	0.00
	1.26	1.09	1.25	0.94	1.04	1.01	1.04	1.34	1.01	1.04	0.54	0.78	0.83	0.57	0.47	0.64	0.61	0.00
10. Ar-Pg	1.50	2.45	2.14	2.16	1.81	2.13	2.06	3.47	1.87	1.49	0.59	0.67	0.28	0.22	0.10	0.25	–0.17	0.00
	1.22	0.60	1.13	0.87	0.79	0.85	0.77	0.74	0.77	0.71	0.63	0.57	0.41	0.41	0.28	0.42	0.41	0.00
11. Ar-Go	0.00	1.15	0.81	0.92	0.81	0.97	1.22	2.22	1.31	0.90	0.91	0.56	0.39	0.19	0.15	0.05	–0.50	0.00
	0.00	0.82	0.82	0.77	0.68	0.74	0.98	1.17	1.05	0.69	0.80	0.52	0.42	0.30	0.44	0.72	1.22	0.00
12. Go-Pg	1.92	2.45	1.39	1.81	1.19	1.75	1.28	1.38	1.16	0.78	0.41	0.48	0.11	0.11	0.08	–0.05	0.25	0.00
	1.32	0.98	1.04	0.98	0.87	0.93	0.84	1.18	0.57	0.71	0.77	0.82	0.58	0.38	0.56	0.28	0.61	0.00
13. B-Pg (MP)	0.58	0.50	0.71	0.31	0.50	0.25	0.41	0.44	0.31	0.13	0.11	0.14	0.09	0.03	0.10	0.05	0.08	0.00
	1.16	0.47	0.58	0.40	0.45	0.37	0.38	0.40	0.27	0.20	0.21	0.29	0.20	0.22	0.21	0.23	0.20	0.00
14. Ar-Go-Gn (°)	–1.17	–1.25	0.16	–0.36	–0.21	–0.50	–0.13	0.00	–0.48	–0.36	–0.54	–0.38	–0.13	0.30	–0.24	0.05	–0.03	0.00
	1.13	1.11	0.79	1.25	1.37	1.37	0.81	1.25	1.12	1.03	0.71	1.11	0.63	0.53	0.59	0.80	0.20	0.00

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-3 Longitudinal Cephalometric Data—Incremental (Female) *(continued)**

DA	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0
P + yrs	–7	–6	–5	–4	–3	–2	–1	P	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
Facial height																		
15. N-ANS (pFH_c)	1.33	1.50	1.29	1.38	0.97	1.13	1.03	0.78	0.74	0.31	0.25	0.06	0.17	0.05	–0.02	0.15	0.00	0.00
	0.75	0.85	0.70	0.62	0.72	0.53	0.62	0.58	0.43	0.45	0.24	0.23	0.24	0.23	0.30	0.24	0.00	0.00
16. ANS-Me (pFH_c)	0.58	1.10	0.79	0.72	1.06	0.69	1.31	1.44	1.23	1.09	0.34	0.35	0.22	0.14	0.05	0.25	0.17	0.00
	0.80	0.70	0.83	0.58	0.83	0.54	0.89	0.79	0.92	0.78	0.32	0.30	0.31	0.23	0.23	0.42	0.41	0.00
17. NF-FHc (°)	0.08	0.50	0.30	–0.11	–0.09	0.38	0.41	–0.22	0.03	–0.13	0.12	0.09	–0.08	0.03	0.10	–0.15	0.08	0.00
	0.49	0.78	0.87	0.65	0.67	0.79	0.95	0.95	0.56	0.50	0.34	0.45	0.41	0.34	0.51	0.47	0.20	0.00
18. MP-FH (°)	0.00	0.55	–0.04	0.06	–0.19	–0.13	–0.56	–0.59	–0.31	–0.44	–0.17	–0.49	0.06	0.23	0.11	0.15	0.17	0.00
	0.32	1.55	1.03	1.20	1.15	0.81	1.06	1.24	0.87	0.70	0.74	0.78	0.68	0.64	0.83	1.11	0.40	0.00
Facial profile																		
19. N-A-Pg (°)	–0.92	–0.40	–1.39	–0.19	–0.91	–0.03	–0.34	–1.03	–0.98	–0.67	–0.17	–0.21	–0.03	–0.27	–0.09	0.20	–0.25	0.00
	1.72	2.08	1.53	1.57	1.11	0.78	1.15	1.30	0.91	0.94	0.76	0.35	0.54	0.82	0.63	1.06	0.61	0.00
20. N-A (FH_c)	0.17	0.00	–0.24	–0.18	0.00	–0.21	0.23	0.24	0.57	0.21	0.32	0.36	0.23	0.06	0.07	–0.05	0.06	0.00
	1.04	0.32	0.79	0.84	0.94	0.87	0.88	0.71	0.65	0.61	1.05	1.15	1.21	0.53	0.43	0.42	0.18	0.00
21. N-B (FH_c)	–0.42	–0.35	–0.31	–0.11	0.59	0.22	0.41	0.81	0.31	0.48	0.15	0.30	–0.20	–0.22	–0.20	0.05	0.17	0.00
	0.97	1.29	0.71	0.92	1.17	1.13	1.36	1.14	0.49	0.79	0.61	0.63	0.63	0.89	0.56	0.64	0.41	0.00
22. N-Pg (FH_c)	0.08	0.05	0.19	0.27	0.56	0.41	0.63	1.13	0.65	0.66	0.18	0.64	–0.29	–0.08	–0.18	0.00	0.33	0.00
	1.43	1.26	0.78	1.04	1.09	0.90	1.18	1.27	0.89	1.02	0.74	0.79	0.93	0.86	0.52	0.78	0.82	0.00
23. A-B(FH_c)	–0.25	0.15	0.16	–0.06	0.59	–0.06	0.25	0.84	0.31	0.48	0.12	0.04	–0.08	0.03	–0.01	–0.15	0.08	0.00
	0.68	0.75	0.76	0.81	0.82	0.70	0.97	0.98	0.51	0.90	0.47	0.48	0.48	0.43	0.41	0.67	0.20	0.00
24. A-B(OP)	0.58	0.10	–0.35	0.19	0.59	–0.50	–0.03	0.28	–0.19	0.16	–0.14	0.16	–0.04	–0.12	0.08	–0.05	0.00	0.00
	0.80	1.82	1.01	0.68	0.76	1.13	1.16	0.71	0.55	0.77	0.70	0.29	0.38	0.36	0.50	0.44	0.00	0.00
25. A-Pg(OP)	0.33	0.90	0.13	0.54	0.59	–0.13	–0.09	0.63	0.00	0.21	0.06	0.11	–0.05	–0.08	0.20	0.10	0.08	0.00
	1.72	1.73	1.50	0.72	0.74	1.16	0.92	1.02	0.81	0.65	1.12	0.76	0.50	0.44	0.59	0.32	0.20	0.00
26. Ar-Go-FH_c	0.83	1.80	–0.12	0.48	0.03	0.25	0.31	–0.69	0.09	0.03	0.33	0.03	0.09	0.01	0.07	0.20	–0.08	0.00
	1.03	1.03	0.85	1.14	1.18	1.14	1.35	1.41	0.87	0.88	0.54	1.03	0.87	0.37	0.65	0.75	0.20	0.00
27. Y-Axis-FH_c (°)	–0.08	0.10	0.24	0.26	–0.34	0.03	–0.09	–0.50	–0.07	–0.18	0.16	–0.32	0.18	0.11	0.00	0.10	–0.17	0.00
	0.80	0.94	0.56	0.61	0.81	0.53	0.55	0.71	0.50	0.70	0.50	0.53	0.51	0.64	0.60	0.52	0.41	0.00
28. Y-Axis (mm)	1.83	2.25	2.46	2.22	2.25	2.09	2.50	3.00	2.13	1.50	0.71	0.48	0.31	0.19	0.13	0.10	0.00	0.00
	1.03	0.75	1.20	1.18	0.80	0.90	0.58	0.77	1.12	0.68	0.64	0.38	0.36	0.44	0.23	0.21	0.00	0.00

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-3 Longitudinal Cephalometric Data—Incremental (Female) *(continued)**

DA	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0
P + yrs	–7	–6	–5	–4	–3	–2	–1	P	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
Dental																		
29. OP-FH_c (°)	0.17	0.05	–0.87	0.51	–0.09	–0.71	–0.65	–0.90	–0.90	–0.60	–0.26	–0.16	0.11	0.05	0.18	0.05	–0.08	0.00
	0.51	1.16	1.70	1.01	1.20	1.40	1.14	0.99	0.68	0.52	0.63	0.39	0.44	0.35	0.55	0.44	0.20	0.00
30. $\underline{1}$-FH_c(°)	1.66	11.25	4.37	–0.21	0.03	–0.47	0.68	0.25	0.91	0.81	0.30	0.23	–0.25	–0.13	–0.03	0.05	0.08	0.00
	404	7.75	8.04	2.29	1.80	1.65	1.65	0.75	1.73	1.04	1.03	0.51	0.93	0.47	0.48	1.11	0.20	0.00
31. $\underline{1}$-A (FH_c)	0.50	1.00	1.32	0.66	0.78	0.00	0.28	0.44	0.40	0.29	0.21	–0.08	0.02	0.01	–0.07	0.15	0.08	0.00
	1.67	1.56	1.30	1.27	0.98	0.77	0.63	0.60	0.63	0.60	0.51	0.34	0.45	0.19	0.46	0.58	0.20	0.00
32. $\underline{1}$-ANS (pFH_c)	–0.08	0.10	0.71	0.97	0.81	0.34	0.53	0.38	0.27	0.26	0.08	0.17	0.09	0.05	0.01	0.15	–0.08	0.00
	3.80	2.57	2.28	1.04	0.59	0.40	0.50	0.39	0.31	0.31	0.26	0.24	0.20	0.18	0.16	0.41	0.20	0.00
33. $\underline{1}$-$\bar{1}$ (°)	0.83	10.25	2.03	–0.75	–1.00	0.40	1.34	0.06	–0.56	–0.81	0.23	–0.05	0.20	–0.08	0.15	0.05	–0.08	0.00
	8.03	15.41	9.96	2.85	3.20	2.32	3.36	1.59	1.87	1.40	1.51	0.94	0.76	1.01	0.66	1.71	0.20	0.00
34. $\bar{1}$-FH_c(°)	–1.67	0.30	–2.22	–1.01	–1.12	0.13	0.66	0.44	0.35	0.06	0.39	0.28	–0.08	–0.20	0.11	0.10	0.00	0.00
	4.73	6.83	2.98	1.56	1.87	2.15	2.32	1.41	0.97	1.00	1.43	0.72	0.85	0.92	0.60	0.91	0.00	0.00
35. $\bar{1}$-I MP (°)	1.83	–0.90	2.30	0.93	1.31	0.00	–0.34	0.38	0.00	0.41	–0.25	0.20	0.02	0.01	–0.05	–0.03	0.17	0.00
	4.52	6.15	3.37	1.74	2.05	2.15	3.02	2.02	0.96	1.23	1.43	1.05	0.96	1.30	1.17	1.64	0.41	0.00
36. $\bar{1}$-Me (pFH_c)	1.42	0.65	0.70	0.64	0.84	0.91	0.78	0.94	0.64	0.67	0.30	0.13	0.11	–0.03	0.10	0.00	0.00	0.00
	0.86	0.71	0.67	0.62	0.54	0.61	0.45	0.77	0.63	0.49	0.30	0.29	0.33	0.34	0.21	0.24	0.00	0.00
37. $\bar{1}$-(N-Pg)	0.42	0.30	0.27	0.48	0.16	0.03	0.03	–0.06	–0.04	–0.07	–0.05	0.02	0.00	0.01	–0.07	0.00	0.08	0.00
	1.49	0.67	0.97	0.33	0.30	0.56	0.76	0.66	0.50	0.52	0.40	0.44	0.20	0.24	0.37	0.41	0.20	0.00
38. $\bar{1}$-(A-Pg)	0.08	0.50	0.63	0.45	0.34	–0.13	0.13	0.23	0.24	0.16	–0.01	0.03	0.04	0.01	–0.07	–0.05	0.17	0.00
	0.80	0.47	0.83	0.58	0.72	0.56	0.62	0.52	0.40	0.51	0.49	0.45	0.24	0.24	0.37	0.28	0.40	0.00

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-4 Longitudinal Cephalometric Data—Incremental (Male)*

DA	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
P + yrs	−10	-9	-8	-7	-6	-5	-4	-3	-2	-1	P	+1	+2	+3	+4	+5	+6	+7
Cranial base																		
1. N-Ar (FH_c)	2.17	1.00	1.41	1.15	1.52	1.51	0.95	0.98	1.07	1.54	1.57	0.94	0.64	0.20	0.30	0.00	0.13	0.17
	1.89	1.22	1.00	0.94	0.77	0.58	0.62	0.64	0.92	0.82	0.76	1.25	0.82	0.74	0.67	0.39	0.23	0.29
2. N-Ba (FH_c)	1.83	1.22	1.82	1.21	1.46	1.18	0.96	1.39	0.89	1.39	1.43	1.11	0.75	0.14	0.25	0.18	0.06	0.17
	0.76	0.83	0.70	0.62	0.72	0.80	0.82	1.10	0.56	0.79	0.98	1.13	0.78	0.23	0.43	0.34	0.18	0.29
3. Ar-Ptm (FH_c)	1.50	0.50	0.48	0.82	0.81	0.87	0.45	0.37	0.54	0.68	0.54	0.71	0.20	-0.01	-0.01	-0.05	0.00	0.17
	1.32	1.10	0.94	0.69	0.59	0.55	0.62	0.61	0.60	0.72	0.72	0.80	0.50	0.47	0.40	0.35	0.00	0.29
4. S-N	0.67	0.72	1.11	1.19	0.59	0.69	0.74	0.69	0.39	0.96	1.21	0.89	0.64	0.31	0.26	0.48	0.06	0.00
	0.76	0.51	0.85	0.66	0.44	0.50	0.54	0.57	0.40	0.63	0.38	0.59	0.57	0.34	0.45	0.15	0.18	0.00
5. S-Ar	1.33	0.88	0.73	0.88	1.01	0.86	0.79	0.71	0.71	0.61	1.04	0.50	0.39	0.31	0.11	-0.09	-0.06	0.00
	0.29	1.04	0.87	0.69	0.62	0.53	0.87	0.62	0.67	0.56	0.97	0.59	0.45	0.35	0.18	0.20	0.32	0.00
6. N-S-Ar (°)	0.67	0.75	0.33	-0.62	0.84	0.26	0.04	0.07	0.32	0.14	-0.04	-0.46	-0.12	-0.16	0.14	0.09	-0.06	0.00
	2.30	2.44	1.37	1.46	1.81	0.70	1.22	1.07	1.25	1.05	1.20	1.37	1.21	0.97	0.73	0.54	0.42	0.00
Maxilla and mandible																		
7. PNS-ANS (FH_c)	1.33	0.88	0.52	0.62	0.96	0.96	0.70	0.59	1.04	1.04	1.39	0.75	0.49	0.21	0.16	0.00	0.06	0.00
	1.53	1.15	0.56	0.51	0.77	0.72	0.59	0.60	0.80	1.01	0.98	0.73	0.56	0.41	0.41	0.00	0.06	0.00
8. PNS-A (FH_c)	0.83	0.67	0.48	0.13	0.82	0.46	0.38	0.76	1.00	1.14	1.21	0.71	0.69	0.16	0.19	0.05	0.06	0.17
	0.76	0.98	0.78	0.65	0.61	0.82	0.61	0.56	0.68	0.60	0.85	0.58	0.67	0.44	0.44	0.15	0.18	0.29
9. Ar-Pg (FH_c)	2.17	1.08	2.32	1.35	2.24	1.41	1.44	1.31	1.99	2.09	1.64	2.04	1.66	0.87	0.75	0.05	-0.13	0.00
	1.04	0.66	1.35	1.03	1.45	1.60	1.17	1.16	1.32	1.10	1.49	1.68	1.32	1.16	1.38	0.79	0.23	0.00
10. Ar-Pg	2.67	1.92	2.85	2.09	2.41	2.26	1.68	1.93	2.20	1.73	4.75	2.29	1.88	0.99	0.60	0.23	0.19	0.00
	0.76	1.16	1.66	1.16	0.98	0.67	0.77	0.96	0.72	1.15	1.22	0.99	0.86	0.70	0.68	0.41	0.37	0.00
11. Ar-Go	0.17	0.67	1.55	0.72	0.95	0.91	0.86	0.93	1.38	1.59	3.04	1.46	1.76	0.71	0.96	0.05	0.35	0.23
	0.29	0.61	1.07	0.80	0.90	0.82	1.26	0.47	1.08	0.96	1.20	0.82	1.06	0.47	0.95	0.15	0.49	0.40
12. Go-Pg	2.67	2.00	1.86	2.35	2.07	1.75	1.54	1.71	1.13	2.62	2.68	2.00	1.26	0.52	0.19	0.23	-0.03	-0.10
	0.58	1.14	0.98	1.01	0.51	1.09	0.83	0.81	1.06	1.02	1.34	1.06	1.12	0.82	0.41	0.47	0.07	0.17
13. B-Pg (MP)	0.00	0.38	0.25	0.19	0.66	0.41	0.41	0.23	0.29	0.36	0.38	0.52	0.23	0.06	0.16	-0.05	0.00	0.00
	0.00	0.38	0.50	0.56	0.58	0.34	0.37	0.28	0.43	0.41	0.54	0.59	0.44	0.15	0.30	0.27	0.00	0.00
14. Ar-Go-Gn (°)	-1.00	-1.00	-0.72	-1.46	-0.76	-0.41	-0.53	-0.36	0.21	-1.18	-1.18	-1.07	-1.23	0.11	-0.25	-0.23	0.35	-0.10
	0.87	2.12	1.17	1.20	0.77	1.14	0.99	1.11	1.45	1.37	1.17	1.19	1.44	0.92	1.04	0.41	0.76	0.17

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-4 Longitudinal Cephalometric Data—Incremental (Male) *(continued)**

DA	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
P + yrs	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	P	+1	+2	+3	+4	+5	+6	+7
Facial height																		
15. N-ANS (pFH_c)	1.00	1.47	1.34	1.42	1.46	1.36	0.81	1.05	0.77	1.59	1.46	0.50	0.49	0.19	0.07	0.09	0.00	0.00
	0.87	0.85	0.83	0.70	1.03	0.79	0.61	0.65	0.61	0.79	0.95	0.71	0.59	0.42	0.18	0.38	0.00	0.00
16. ANS-Me (pFH_c)	2.00	0.85	1.05	1.04	0.74	1.26	0.84	1.23	1.02	1.59	2.89	1.79	0.76	0.76	0.41	0.27	0.13	0.17
	1.00	0.74	0.91	1.23	0.72	0.84	0.53	1.27	0.81	1.20	1.40	1.38	0.72	0.76	0.48	0.47	0.23	0.29
17. NF-FHc (°)	-0.50	-0.50	0.10	0.26	0.31	0.09	0.75	-0.11	-0.07	0.11	-0.25	-0.18	-0.36	-0.27	0.02	0.05	0.10	-0.10
	0.87	0.95	0.96	0.93	0.86	1.02	2.49	0.76	0.51	0.86	0.96	0.93	1.22	0.45	0.52	0.42	0.19	0.36
18. MP-FH (°)	-0.17	-0.17	-0.45	-0.29	-0.51	0.01	-0.11	-0.57	-0.29	-0.29	-0.50	-0.61	-0.94	-0.50	-0.38	-0.09	-0.09	-0.10
	0.58	1.26	0.57	0.79	1.01	1.25	1.30	1.30	1.52	0.73	1.07	1.32	0.87	0.75	0.61	0.30	0.18	0.17
Facial profile																		
19. N-A-Pg (°)	-0.42	-1.65	-0.18	-1.39	-0.64	-0.05	-0.24	0.39	-0.39	-0.89	-0.66	-0.64	-0.57	-0.66	-0.05	0.06	0.00	
	2.84	0.86	1.95	1.21	1.13	0.77	1.32	1.01	1.27	1.02	1.85	1.04	1.25	0.96	0.74	0.57	0.18	0.00
20. N-A (FH_c)	0.17	0.00	-0.23	-0.18	0.00	-0.21	0.23	0.24	0.57	0.21	0.32	0.36	0.23	0.06	0.07	-0.05	0.06	0.00
	1.04	0.32	0.79	0.84	0.94	0.87	0.88	0.71	0.65	0.61	1.05	1.15	1.21	0.53	0.43	0.42	0.18	0.00
21. N-B (FH_c)	0.33	-0.38	0.29	-0.22	0.48	-0.34	0.23	0.34	0.68	0.21	0.54	0.91	0.69	0.54	0.25	0.00	-0.16	-0.23
	1.52	0.68	1.75	1.21	1.37	1.27	1.27	1.38	1.32	1.09	1.03	1.80	1.65	0.85	0.80	1.07	0.35	0.25
22. N-Pg (FH_c)	0.17	0.17	0.79	0.29	0.82	-0.21	0.59	0.41	0.79	0.54	1.14	1.12	1.00	0.76	0.30	0.05	-0.25	-0.17
	0.76	1.17	2.02	1.54	1.48	1.78	1.53	1.38	1.67	0.87	1.76	2.05	1.84	1.11	1.12	0.96	0.46	0.29
23. A-B(FH_c)	0.50	-0.38	0.48	0.19	0.26	-0.01	-0.07	0.18	0.07	-0.04	0.00	0.76	0.43	0.11	0.26	0.09	-0.29	-0.23
	0.87	0.68	1.62	1.22	1.22	0.80	0.76	1.27	0.98	0.75	0.65	1.40	1.00	1.76	0.51	0.83	0.36	0.25
24. A-B(OP)	0.17	0.42	0.59	0.31	0.06	0.09	-0.41	-0.12	-0.20	-0.12	-0.32	-0.04	0.05	0.08	0.30	0.27	0.38	0.50
	0.76	1.07	1.69	1.09	0.73	0.99	0.78	0.90	1.23	1.12	1.09	0.82	0.90	0.70	0.70	0.88	0.74	0.50
25. A-Pg(OP)	0.00	1.08	1.21	0.78	0.25	0.46	-0.07	-0.36	-0.11	0.36	-0.14	0.34	-0.14	-0.05	0.53	0.05	0.31	0.00
	1.32	1.59	2.35	1.60	1.41	1.12	0.28	1.03	1.43	1.35	1.12	1.00	0.90	1.07	0.93	0.57	0.88	0.00
26. Ar-Go-FH_c	0.83	0.22	0.50	1.36	0.07	0.57	0.27	0.62	-0.93	1.11	0.68	0.36	0.31	-0.51	-0.09	0.27	-0.40	0.07
	0.29	1.13	1.37	1.26	0.98	1.24	1.07	1.66	1.21	1.52	1.15	1.59	2.11	1.34	0.87	0.41	0.71	0.12
27. Y-Axis-FH_c (°)	0.17	0.13	-0.20	0.12	-0.14	0.18	-0.01	-0.02	0.02	-0.06	0.04	-0.50	-0.10	-0.32	-0.04	0.00	0.16	0.07
	0.29	0.38	0.48	0.82	0.95	0.75	0.78	0.54	0.70	0.57	0.63	0.92	0.82	0.88	0.41	0.32	0.23	0.12
28. Y-Axis (mm)	3.17	2.22	2.84	2.77	2.34	2.26	2.08	2.21	2.25	3.43	4.68	2.86	1.84	1.07	0.51	0.14	0.29	0.07
	0.58	1.18	1.54	1.59	0.92	0.92	0.71	0.86	0.83	1.19	1.19	1.71	0.81	0.65	0.59	0.32	0.36	0.12

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-4 Longitudinal Cephalometric Data—Incremental (Male) *(continued)**

DA	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
P + yrs	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	P	+1	+2	+3	+4	+5	+6	+7
Dental																		
29. OP-FH_c (°)	−1.50	1.33	−0.03	0.35	−0.41	−0.06	−0.59	−0.63	−0.50	−0.75	−1.11	−0.80	−0.57	−0.79	0.09	0.05	−0.06	−0.33
	1.80	1.40	1.31	1.38	1.36	1.55	1.03	0.72	1.36	1.46	1.38	1.26	0.97	1.12	0.97	0.52	0.62	1.04
30. $\underline{1}$-FH_c(°)	7.00	3.83	2.44	3.55	1.29	0.61	−0.51	0.05	0.25	0.00	−0.68	0.27	0.34	0.24	0.26	−0.27	0.06	0.00
	7.00	6.85	4.55	4.75	2.61	2.06	1.69	1.88	2.07	1.63	2.45	1.44	1.39	1.38	1.24	1.78	0.32	0.00
31. $\underline{1}$-A (FH_c)	−0.19	1.95	0.50	0.48	1.18	0.82	−0.12	0.23	0.20	−0.02	0.11	0.21	0.04	0.29	0.11	−0.23	0.06	0.17
	1.26	0.94	1.30	1.23	1.15	1.09	0.56	0.74	0.57	0.57	1.00	0.61	0.77	0.69	0.45	0.61	0.18	0.29
32. $\underline{1}$-ANS (pFH_c)	0.67	0.42	0.00	0.19	1.74	0.93	0.34	0.48	0.38	0.34	0.61	0.43	0.24	0.12	0.07	0.00	0.29	0.06
	0.76	1.28	1.64	3.80	2.49	1.19	0.90	0.64	0.35	0.50	0.81	0.65	0.40	0.46	0.33	0.22	0.45	0.12
33. $\underline{1}$-$\bar{1}$ (°)	13.83	0.00	−2.06	0.98	−1.11	−0.61	−0.19	−0.20	0.50	0.21	0.64	0.50	0.76	0.72	−0.01	0.36	0.00	0.17
	10.72	11.78	5.24	8.55	4.51	4.50	2.36	2.78	2.29	2.31	2.37	1.84	1.92	2.77	0.88	1.73	0.38	0.76
34. $\bar{1}$-FH^c(°)	0.33	−3.67	−0.15	−0.37	−1.43	−1.00	−0.75	0.57	0.82	0.21	−0.07	0.66	0.95	1.16	0.23	0.18	0.06	0.17
	9.25	3.01	4.83	4.52	3.02	2.38	1.50	2.01	2.00	1.63	1.95	1.23	1.44	1.99	1.07	0.34	0.68	0.76
35. $\bar{1}$-MP (°)	1.00	3.20	−0.57	0.74	1.94	0.99	0.84	−0.34	−0.18	0.07	0.50	0.01	−0.07	−0.52	0.08	−0.27	0.03	0.10
	8.67	3.53	5.35	4.81	3.18	2.02	1.87	2.06	1.76	2.11	2.01	1.38	1.57	1.43	1.35	0.41	0.77	0.36
36. $\bar{1}$-Me (pFH_c)	1.83	0.47	1.14	0.71	0.84	0.73	0.66	0.76	0.77	1.30	1.63	1.11	0.68	0.38	0.26	0.00	0.10	0.23
	0.76	1.06	0.80	0.53	0.63	0.46	0.41	0.50	0.62	0.96	0.67	0.81	0.42	0.40	0.37	0.00	0.28	0.40
37. $\bar{1}$-(N-Pg)	−0.50	0.33	0.91	0.50	0.25	0.36	−0.05	−0.13	0.12	−0.04	−0.07	−0.12	−0.27	−0.15	−0.14	−0.09	−0.08	0.13
	1.32	0.93	2.20	0.96	0.38	0.74	0.70	0.55	0.63	0.60	0.43	0.48	0.51	0.26	0.23	0.38	0.30	0.12
38. $\bar{1}$-(A-Pg)	−0.33	0.47	0.52	0.65	0.39	0.46	0.04	−0.32	0.13	0.12	−0.07	0.18	−0.07	−0.05	0.12	−0.14	0.08	0.13
	1.89	1.09	1.07	0.92	0.45	0.72	0.77	0.82	0.56	0.56	0.68	0.42	0.33	0.35	0.29	0.64	0.30	0.12

*DA indicates developmental age; P + yrs indicates number of years beyond puberty. For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-5 Soft Tissue Analysis*

	Chronological age						
						Female	Male
	5.3	8.3	10.4	12.3	14.6	21.2	27.4
1. UL (Sn-Pg') (mm)	4.7	4.7	4.6	3.4	2.8	1.9	2.1
	1.84	1.30	1.55	1.76	1.95	1.18	1.05
2. LL (Sn-Pg') (mm)	3.4	4.1	4.0	2.8	1.8	1.8	2.1
	1.71	1.58	1.73	1.81	1.52	1.33	2.00
3. G'-Sn-Pg' (°)	13.5	14.6	14.0	13.1	12.1	16.7	12.2
	5.60	4.96	4.58	5.75	5.28	5.91	3.63
4. Rn-Sn(FH_C) (mm)	9.5	9.8	10.8	12.7	13.3	12.9	16.4
	1.06	1.18	1.27	1.05	1.42	1.12	1.25
5. Pn-Sn(FH_C) (mm)	11.6	12.8	13.4	13.1	15.7	16.2	16.8
	1.35	1.58	1.34	2.10	1.89	1.26	0.85
6. Sn-N-Pg (°)	23.5	23.9	25.0	22.8	25.0	24.9	24.0
	1.74	2.10	2.24	2.47	2.38	2.00	1.18
7. Pn-Sn-UL (°)	115.3	116.3	114.1	110.8	116.7	110.8	112.5
	7.85	6.92	8.41	6.15	7.67	5.94	3.90
8. UL Incli (°)	99.9	100.9	97.5	91.2	92.5	90.7	90.2
	7.75	9.65	7.54	8.46	8.89	7.82	3.31
9. LL Incli (°)	34.3	29.7	36.8	41.5	40.1	46.1	42.1
	7.51	8.10	9.15	10.8	9.61	11.2	9.10
10. UL (Esthetic Plane) (mm)	0.0	-0.6	-1.1	-2.7	-4.8	-5.6	-5.9
	2.60	1.41	1.72	2.55	1.78	1.81	1.73
11. LL (Esthetic Plane) (mm)	0.7	0.7	0.2	-1.2	-3.8	-3.9	-3.2
	1.89	1.84	2.20	2.45	2.63	2.29	2.21
12. Mandibular Sulcus (mm)	-2.5	-2.8	-3.3	-3.8	-4.9	-4.3.	-5.1
	0.78	1.18	1.30	1.38	1.52	1.22	1.02
13. Maxillary Sulcus (mm)	-1.5	-1.5	-1.6	-1.7	-1.8	-1.5	-2.0
	0.36	0.36	0.58	0.65	0.61	0.42	0.55
14. Sn-Stm (pFH_C) (mm)	18.1	18.8	19.8	19.9	20.0	18.8	23.5
	1.73	1.55	2.10	2.35	2.53	2.42	2.05
15. UL-Is (mm)	1.8	2.2	2.5	2.3	2.6	3.1	2.2
	1.52	0.95	0.82	1.06	0.89	0.74	0.82
16. Si-Stm (pFH_C) (mm)	13.5	15.1	15.7	16.3	16.5	16.9	18.2
	1.32	0.96	0.84	1.58	1.28	1.83	2.04
17. Me'-Si (pMP) (mm)	24.3	27.3	28.1	28.4	29.4	30.9	32.3
	3.63	3.50	3.37	3.27	3.63	2.95	3.32
18. A-Sn (FH_C) (mm)	12.0	13.9	14.5	15.6	16.0	15.3	19.7
	1.00	0.99	1.56	1.94	1.73	1.56	1.40
19. Is-UL (FH_C) (mm)	13.4	12.5	12.0	11.8	12.6	10.9	13.7
	1.90	1.57	1.85	1.82	2.13	1.62	2.21
20. Ii-LL (FH_C) (mm)	12.5	13.0	12.9	12.9	13.4	12.9	15.5
	1.92	1.71	2.01	1.50	2.21	1.84	1.92
21. Pg-Pg' (FH_C) (mm)	10.7	11.8	12.1	10.8	12.2	11.1	13.3
	1.53	1.45	1.82	1.64	2.38	1.81	1.65

*For each numbered landmark, the first line is the mean and the second line is the standard deviation.

Table B-6 Soft Tissue Analysis–Adult Standards

Measurement	Landmarks	Mean	Standard deviation
Facial form			
Angle of facial convexity (°)	G'-Sn-Pg'	12	4
Maxillary prognathism (mm)	G'-Sn (FH_C)[1]	6	3
Mandibular prognathism (mm)	G'-Pg' (FH_C)	0	4
Vertical height ratio	G'-Sn/Sn-Me' (pFH_C)[2]	1	
Lower face-throat angle (°)	Sn-Gn'-C	100	7
Lower vertical height-depth ratio	Sn-Me'/C-Pg'	1.2	
Lip position and form			
Nasiolabial angle (°)	Pn-Sn-UL	102	8
Upper lip protrusion (mm)	UL to (Sn-Pg')	3	1
Lower lip protrusion (mm)	UL to (Sn-Pg')	2	1
Mentolabial sulcus (mm)	Si to (LL-Pg')	4	2
Vertical lip-chin ratio	Sn-Stm/Stm-Me'(FH_C)[1]	0.5	
Maxillary incisor exposure (mm)	UL-Is	2	2
Interlabial gap (mm)	UL-LL (pFH_C)[2]	2	2

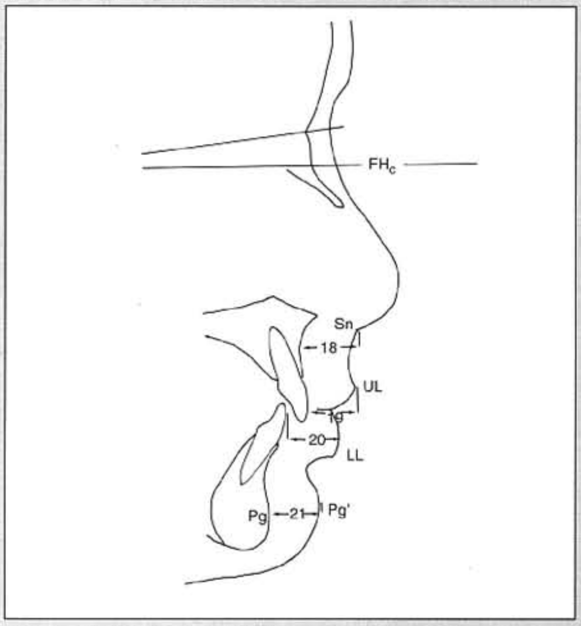
[1] (FH_C) indicates that the measurement is made parallel to the constructed Frankfort horizontal.
[2] (pFH_C) indicates that the measurement is made perpendicular to the constructed Frankfort horizontal.

(continued from page 236)

18. A-Sn (FH_c): Point A to subnasale, measured parallel to the FH_c line. This is a measurement of the thickness of the base of the upper lip. For this thickness measurement to be accurate, the lips should be at rest when the cephalogram is taken. Lips might be in contact while at rest, but the operator needs to know this. During the teenage years, this measurement of the base of the upper lip is usually about 16 mm. This measurement then becomes the "benchmark" for the patient. The thickness of the upper lip, lower lip, and soft tissue chin can be related to this "benchmark" measurement by the numbers 4, 3, 4; that is, the upper lip is usually about 4 mm less than the benchmark measurement, the lower lip is about 3 mm less, and the soft tissue chin is about 4 mm less.

19. Is-UL (FH_c): Incision superioris to upper lip, measured parallel to the FH_c line. This is a measurement of the thickness of the upper lip. During the teenage years, the upper lip is typically about 4 mm less than the benchmark measurement, or about 12 mm. But again, each patient's benchmark measurement is different. For example, a patient with an upper lip base thickness (A-Sn[FH_c]) of 18 mm should have a normal upper lip thickness of 18 – 4, or 14 mm. If this upper lip were 12 mm, this patient would have an upper lip that was 2 mm thinner than the benchmark measurement.

20. Ii-LL (FH_c): Incision inferioris to lower lip, measured parallel to the FH_c line. This is a measurement of the lower lip thickness. For the patient shown in this figure, the lower lip thickness is really a measurement from the lower lip to the labial surface of the upper incisor, rather than to the labial surface of the lower incisor. Therefore, although the measurement reads Ii-LL (FH_c), for this particular patient the lower lip thickness is more reasonably made to the labial surface of



the upper incisor rather than to the labial surface of the lower incisor and the greatest width may not be found parallel to the FH_c line. Other patients could be entirely different, but the measurement of the lower lip thickness must be reasonable. The normal lower lip thickness is usually about 3 mm less than the benchmark measurement (A-Sn[FH_c]).

21. Pg-Pg' (FH_c): Hard tissue pogonion to soft tissue pogonion, measured parallel to the FH_c line. This is a measurement of the thickness of the soft tissue chin. Typically, for the teenage years, the base of the upper lip (A-Sn[FH_c]) is about 16 mm; therefore, the soft tissue chin would typically be about 12 mm (16 – 4 = 12).

Appendix C

Growth-Prediction Methods: How to Improve Accuracy

Hard tissue growth predictions usually cover the period of treatment (2 years in most instances) or longer, as a long-range forecast of growth of the jaws from the mixed dentition to the adult dentition. Growth prediction increments (Tables C-1 and C-2) are added for each of several cephalometric measurements, depending on the number of years of the growth prediction. These growth predictions will show how the relationship of the jaws will change as a result of the projected growth; when the soft tissue growth prediction increases in accuracy, it will be added to the hard tissue growth prediction.

The Growth Prediction Increments tables show the incremental growth for each age. In the female group (Table C-1), for instance, the incre-

Table C-1 Growth Prediction Increments for Females*

Dev age	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0
P ± yrs	−7	−6	−5	−4	−3	−2	−1	P	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
S-N (mm)																		
average	0.92	1.25	0.86	0.59	0.75	0.88	0.63	1.00	0.56	0.47	0.13	0.13	0.16	0.09	0.13	−0.05	0.00	0.00
1σ	0.58	0.42	0.50	0.46	0.52	0.50	0.65	0.41	0.44	0.43	0.29	0.22	0.30	0.20	0.23	0.16	0.00	0.00
%C	88.8	89.8	90.8	92.1	93.0	94.0	95.3	96.2	97.6	98.5	99.2	99.4	99.5	99.8				
N-ANS (pFH_c) (mm)																		
average	1.33	1.50	1.29	1.38	0.97	1.13	1.03	0.78	0.74	0.31	0.25	0.06	0.17	0.05	−0.02	0.15	0.00	0.00
1σ	0.75	0.85	0.70	0.62	0.72	0.53	0.62	0.58	0.43	0.45	0.24	0.23	0.24	0.23	0.30	0.24	0.00	0.00
%C	78.6	79.9	83.6	86.2	89.0	90.8	93.2	95.2	96.8	98.2	98.8	99.4	99.4	99.8				
PNS-ANS (FH_c) (mm)																		
average	0.67	0.55	0.82	0.75	0.59	1.00	1.09	1.22	0.56	0.31	0.20	0.09	0.16	0.08	0.05	0.05	0.00	0.00
1σ	0.52	0.55	0.67	0.68	0.66	0.91	0.69	1.26	0.62	0.54	0.63	0.20	0.35	0.31	0.14	0.28	0.00	0.00
%C	85.0	85.3	86.7	88.6	89.9	91.0	92.9	95.0	97.3	98.4	99.0	99.4	99.6	99.8				
ΔNasal floor angle = FH_c (°)																		
average	0.08	0.50	0.30	−0.11	−0.09	0.38	0.41	−0.22	0.03	−0.13	0.12	0.09	−0.08	0.03	0.10	−0.15	0.08	0.00
1σ	0.49	0.78	0.87	0.65	0.67	0.79	0.95	0.95	0.56	0.50	0.34	0.45	0.41	0.34	0.51	0.47	0.20	0.00
Gn down the Y-axis (mm)																		
average	1.83	2.25	2.46	2.22	2.25	2.09	2.50	3.00	2.13	1.50	0.71	0.48	0.31	0.19	0.13	0.10	0.00	0.00
1σ	1.03	0.75	1.20	1.18	0.80	0.90	0.58	0.77	1.12	0.68	0.64	0.68	0.36	0.44	0.12	0.21	0.00	0.00
%C	80.7	81.7	83.1	85.2	87.1	89.0	90.8	92.9	95.5	97.2	98.5	99.1	99.5	99.8				
ΔY axis-FH_c (°)																		
average	−0.08	0.10	0.24	0.26	−0.34	0.03	−0.09	−0.05	−0.07	−0.18	0.16	−0.32	0.18	0.11	0.00	0.10	−0.17	0.00
1σ	0.80	0.94	0.56	0.61	0.81	0.53	0.55	0.71	0.50	0.70	0.50	0.53	0.51	0.64	0.60	0.52	0.41	0.00
MP-FH_c (°)																		
average	0.00	0.55	−0.04	0.06	−0.19	−0.13	−0.56	−0.59	−0.31	−0.44	−0.17	−0.49	0.06	0.23	0.11	0.15	0.17	0.00
1σ	0.32	1.55	1.03	1.20	1.15	0.81	1.06	1.24	0.87	0.70	0.74	0.78	0.68	0.64	0.83	1.11	0.40	0.00
Ii-A-Pg (mm)																		
average	0.08	0.50	0.63	0.45	0.34	−0.13	0.13	0.23	0.24	0.16	−0.01	0.03	0.04	0.01	−0.07	−0.05	0.17	0.00
1σ	0.80	0.47	0.81	0.58	0.72	0.56	0.62	0.52	0.40	0.51	0.49	0.45	0.24	0.24	0.37	0.28	0.40	0.00
/1-Me ÷ ANS-Me (%)																		
average	0.58	0.60	0.59	0.60	0.60	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
OP-FH_c (°)																		
average	0.17	0.05	−0.87	0.51	−0.09	−0.71	−0.65	−0.90	−0.90	−0.60	−0.26	−0.16	0.011	0.05	0.18	0.05	−0.08	0.00
1σ	0.51	1.16	1.70	1.01	1.20	1.70	1.14	0.99	0.68	0.52	0.63	0.39	0.44	0.35	0.55	0.44	0.20	0.00

*Dev age indicates developmental age; P ± yrs indicates number of years before or beyond puberty.

Table C-2 Growth Prediction Increments for Males*

Dev age	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
P ± yrs	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	P	+1	+2	+3	+4	+5	+6	+7
S-N (mm)																		
average	0.67	0.72	1.11	1.19	0.59	0.69	0.74	0.69	0.39	0.96	1.21	0.89	0.64	0.31	0.26	0.48	0.06	0.00
1σ	0.76	0.51	0.85	0.66	0.44	0.50	0.54	0.57	0.40	0.63	0.38	0.59	0.57	0.34	0.45	0.15	0.18	0.00
%C	87.0	87.0	97.2	88.6	89.9	90.7	91.7	92.8	93.7	94.1	95.5	97.1	98.3	99.3	99.7			
N-ANS (pFH_c) (mm)																		
average	1.00	1.47	1.34	1.42	1.46	1.36	0.81	1.05	0.77	1.59	1.46	0.50	0.49	0.19	0.07	0.09	0.00	0.00
1σ	0.87	0.85	0.83	0.70	1.03	0.79	0.61	0.65	0.61	0.79	0.95	0.71	0.59	0.42	0.17	0.38	0.00	0.00
%C	76.1	77.9	78.6	79.9	82.3	84.8	87.4	88.8	90.8	92.1	95.0	97.8	98.7	99.6	100.0			
PNS-ANS (FH_c) (mm)																		
average	1.33	0.88	0.52	0.62	0.96	0.96	0.70	0.59	1.04	10.4	1.39	0.75	0.49	0.21	0.16	0.00	0.06	0.00
1σ	1.53	1.15	0.56	0.51	0.77	0.82	0.59	0.60	0.80	1.01	0.98	0.73	0.56	0.41	0.41	0.00	0.06	0.00
%C	80.8	83.1	83.9	85.0	85.5	87.4	89.1	90.7	91.2	93.1	96.4	97.2	98.6	99.3	99.8			
ΔNasal floor angle = FH_c (°)																		
average	−0.05	−0.05	0.10	0.26	0.31	0.09	0.75	−0.11	−0.07	0.11	−0.25	−0.18	−0.36	−0.27	0.02	0.05	0.10	−0.10
1σ	0.87	0.95	0.96	0.93	0.86	1.02	2.49	0.76	0.51	0.86	0.96	0.93	1.22	0.45	0.52	0.42	0.19	0.36
Gn down the Y-axis (mm)																		
average	3.17	2.22	2.84	2.77	2.34	2.26	2.08	2.21	2.25	3.43	4.68	2.86	1.84	1.07	0.51	0.14	0.29	0.07
1σ	0.58	1.18	1.54	1.59	0.92	0.92	0.71	0.86	0.83	1.19	1.19	1.71	0.81	0.65	0.59	0.32	0.36	0.12
%C	75.0	76.6	77.6	78.9	81.3	82.5	84.2	85.8	87.4	89.1	91.7	95.2	97.4	98.7	99.5			
ΔY axis-FH_c (°)																		
average	0.17	0.13	−0.20	0.12	−0.14	0.18	−0.01	−0.02	0.02	−0.06	0.04	−0.05	−0.10	−0.32	−0.04	0.00	0.16	0.07
1σ	0.29	0.38	0.48	0.82	0.95	0.75	0.78	0.54	0.70	0.57	0.63	0.92	0.82	0.88	0.41	0.32	0.23	0.12
MP-FH_c (°)																		
average	−0.17	−0.17	−0.45	−0.29	−0.51	0.01	−0.11	−0.57	−0.29	−0.29	−0.50	−0.61	−0.94	−0.50	−0.38	−0.09	−0.09	−0.10
1σ	0.58	1.26	0.57	0.79	1.01	1.25	1.30	1.30	1.52	0.73	1.07	1.32	0.87	0.75	0.61	0.30	0.18	0.17
li-A-Pg (mm)																		
average	−0.33	0.47	0.52	0.65	0.39	0.46	0.04	−0.32	0.13	0.12	−0.07	0.18	−0.07	−0.05	0.12	−0.14	0.08	0.13
1σ	1.89	1.09	1.07	0.92	0.45	0.72	0.77	0.82	0.56	0.56	0.68	0.42	0.33	0.35	0.29	0.64	0.30	0.12
/1-Me ÷ ANS-Me (%)																		
average	0.56	0.59	0.60	0.61	0.61	0.61	0.61	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.60
OP-FH_c (°)																		
average	−1.50	1.33	−0.03	−0.35	−0.41	−0.06	−0.59	−0.63	−0.50	−0.75	−1.11	−0.80	−0.57	−0.79	0.09	0.05	−0.06	−0.33
1σ	1.80	1.40	1.31	1.38	1.36	1.55	1.03	0.72	1.36	1.46	1.38	1.26	0.97	1.12	0.97	0.52	0.62	1.04

*Dev age indicates developmental age; P ± yrs indicates number of years before or beyond puberty.

ment of growth at the peak growth velocity (P), or 12.0 years, is 1.00 mm. This represents the average amount of growth of this measurement between 11.5 and 12.5 years. Females are reported on whole years because their peak velocity (11 years, 8 months) is closest to a whole year. Males, on the other hand, are reported on the half year because their peak velocity (14 years 6 months) is on the half year. Each age thus can be expressed as so many years plus or minus the peak growth velocity; that is, a 16-year, 6-month-old male can also be described as a male P + 2 years past his peak growth velocity.

Included for each increment of growth is one standard deviation on either side of the mean and the percentage of completed growth (%C) that this increment represents.

Preparing a growth prediction requires two identical tracings (in black) of the lateral headfilm, each on a separate sheet of tracing paper; for illustration purposes, one of the tracings will be labeled tracing A and the other tracing B. Tracing A is the tracing (in black) on which the growth prediction will be drawn (in blue); tracing B will be used as a tracing template and will be slipped under tracing A to copy the structures. Tracing B can be the tracing on which the original cephalometric analysis was done. Both tracings should show the constructed Frankfort horizontal line. The facial age of the patient must be known, and the relevant (male or female) growth prediction increments (Tables C-1 and C-2) will be used.

Our example, patient RR, a male with a facial age of 14 years 0 months, presents with a Class II, division 1 malocclusion; his molar relationship is a full-cusp bilateral Class II. A 2-year growth prediction will be prepared to determine if and how growth can be used for the correction of the Class II malocclusion. Thus, his growth prediction period will be from 14.0 years to 16.0 years. The growth prediction will start with the cranial base (increase in the sella-nasion length), the maxilla (descent, increase in length and rotation, if applicable) and mandible (repositioning of gnathion down the Y-axis and any mandibular rotation, if applicable). If desired, the movement of the dentition can be predicted as part of the growth prediction.

The growth of the cranial base is taken as the increase in length of the measurement sella to nasion and measured at nasion. The amount of this increase will be found in the table of growth prediction increments for males; this table is arranged according to the half year because the peak velocity of growth for males occurs at 14 years 6 months. The growth increments at 12.5 years and 13.5 years (the amount of growth between 12.0 and 13.0 years and between 13.0 and 14.0 years, respectively) can also be described as the growth increment from P–2 years and P–1 year, where P represents 14.5 years. P+1 year for a male is 15 years 6 months; P+1 year for a female is 13 years 0 months (since the female peak velocity of growth is taken as 12 years 0 months).

Using these charts, one can establish the new position of nasion by projecting the growth increments along the sella-nasion line. The two columns labeled 14.5 and 15.5 show that the incremental change for sella-nasion is 1.21 mm and 0.89 mm, respectively, for a total of 2.10 mm.

The growth prediction tracing ("A") is placed over a sheet of millimeter graph paper with the S-N line positioned over a dark horizontal line and with nasion positioned over a dark vertical line; a dot is placed 2.1 mm anterior to nasion along the sella-nasion line (Fig C-2a). Next, tracing "A" is placed over the second tracing ("B"), and both tracings are superposed along the S-N line at nasion. The template is slid forward so that the "new nasion" is at the dot. The two tracings can be taped together to prevent movement while the new nasion is traced (in blue). The contours of the frontal bone will remain roughly parallel to the original.

To determine the position of the new maxilla, the increments of the vertical descent and horizontal movement of the maxilla are found on the growth prediction increments for males table (Table C-2). The vertical descent of the anterior nasal spine (nasion–anterior nasal spine [pFH$_c$]) is 1.46 mm between 14 and 15 years and 0.50 mm between 15.0 and 16.0 years for a total of 1.96 mm descent. The forward movement of the anterior nasal spine, PNS-ANS(FH$_c$), is listed as 1.39 mm between 14.0 and 15.0 years and as 0.75 mm between 15.0 and 16.0 years, for a total of 2.14 mm.

To plot the new position of the anterior nasal spine, a dot is placed 1.96 mm (about 2 mm) infe-

rior and 2.14 (about 2 mm) anterior to the original anterior nasal spine, perpendicular and parallel, respectively, to the FH_c (Fig C-2b). The easiest way to do this is to place the growth prediction tracing ("A") over a sheet of millimeter graph paper with the constructed Frankfort horizontal parallel to the horizontal lines, positioning ANS over the intersection of a dark horizontal and dark vertical line. Place a dot about 2 mm below and 2 mm anterior to the original ANS. Next, place the growth prediction tracing over the template tracing ("B"), positioning the just-placed dot representing the "new" position of ANS over the ANS. Redraw the maxilla (in blue) on the growth prediction tracing, keeping the teeth in the same place as if they were ankylosed (Fig C-2d).

For most 2-year growth predictions, the new maxilla can be drawn directly from the template, but take care that the constructed Frankfort horizontal lines are parallel (not superposed) so that there is no rotation of the maxilla or the nasal floor. However, some long-term growth predictions show significant rotation of the maxilla. In this case, the template maxilla ("B") can be rotated the required amount around ANS, minus (–) being counterclockwise and plus (+) being clockwise. The "new maxilla" can then be drawn in blue showing the amount of predicted rotation. If a negative rotation is desired, the template tracing ("B") is taped to the white background and the growth prediction tracing ("A") is superposed over it. The growth prediction tracing can then be rotated "positively" around ANS. This will produce a negative rotation on the growth prediction tracing ("A"). If a positive rotation is desired, the template tracing is secured in the same manner as above, but the growth prediction tracing ("A") can now be rotated negatively around ANS. This will produce a positive rotation on the growth prediction tracing.

To show the growth changes in the mandible, gnathion must be moved down the Y-axis by the required amount. Trace the Y-axis (sella to gnathion) on both tracings (A and B), then add the Y-axis increments for the number of years of the growth prediction. For our patient RR it is 14 to 15 = 4.68 mm and 15 to 16 = 2.86 mm, or 7.54 mm for the 2-year prediction. A dot can now be placed 7.5 mm down the Y-axis (Fig C-2c).

In some long-term growth predictions, or for extreme mandibular growth rotations, a positive or negative change to the mandibular plane angle can be predicted. To show this, the gnathion dot on the new growth prediction tracing (A) can be rotated clockwise around the template gnathion tracing (B) for a counterclockwise rotation or counterclockwise for a clockwise rotation on the growth-prediction tracing.

Once the position of the new gnathion and any rotation of the mandible have been determined, the mandible can be retraced (in blue). The growth prediction tracing (A) is superposed over the Y-axis of tracing B until the just-placed dot is over gnathion on tracing B. The template mandible is retraced, maintaining the position of the teeth as if they were ankylosed. The posterior border of the mandible is also drawn directly over the original mandible (Fig C-2d).

The completed 2-year hard tissue growth prediction for patient RR is shown in Fig C-2d. The denture base relationship can be measured before and after the growth prediction. For patient RR, the initial denture base relationship (A-B[OP]) was –7.0 mm; after 2 years' growth, the denture base relationship measures –4.0 mm, a +3.0 mm change. If growth occurs as predicted and headgear compliance is good, the full-cusp Class II molar relationship can probably be corrected without the extraction of any teeth.

The space between the ankylosed teeth, known as the intermaxillary growth space, does not actually appear since the teeth undergo continuous eruption and the orthodontist can control, mechanically, the amount of eruption of the upper and lower teeth within this space. Thus, the orthodontist has some control over the cant and level of the plane of occlusion. As long as the upper and lower teeth are not erupted past this intermaxillary growth space, the posture of the mandible will not be changed. If teeth are erupted past this amount, the mandible will "hinge open," increasing the difficulty of the Class II correction. Deep overbite can be corrected in patient RR by posterior extrusion without rotating the mandible clockwise.

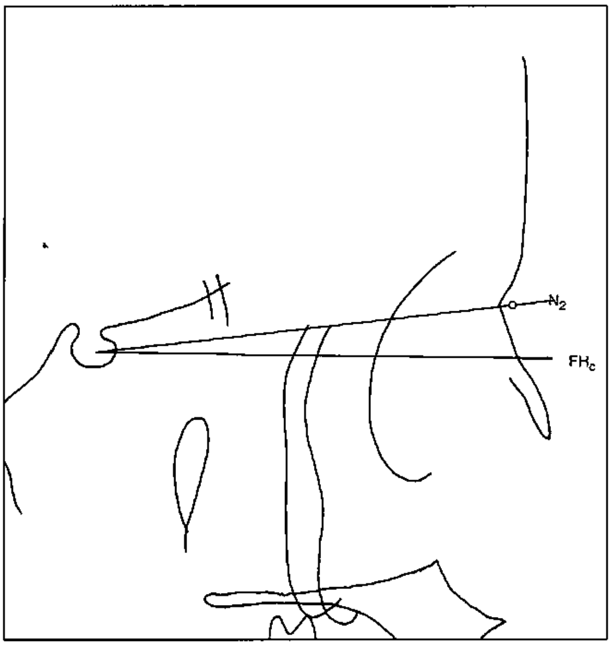


Fig C-2a Nasion and ANS growth increments. Original tracing showing dot of projected growth increment along S-N line.

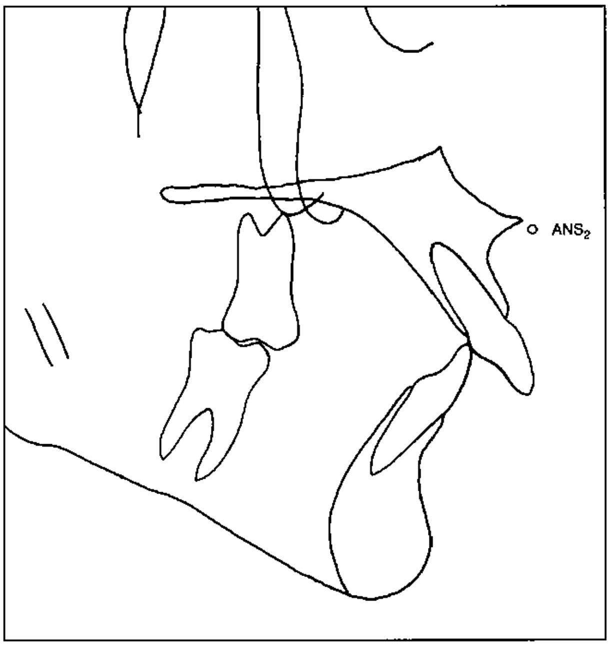


Fig C-2b New position of ANS is marked.

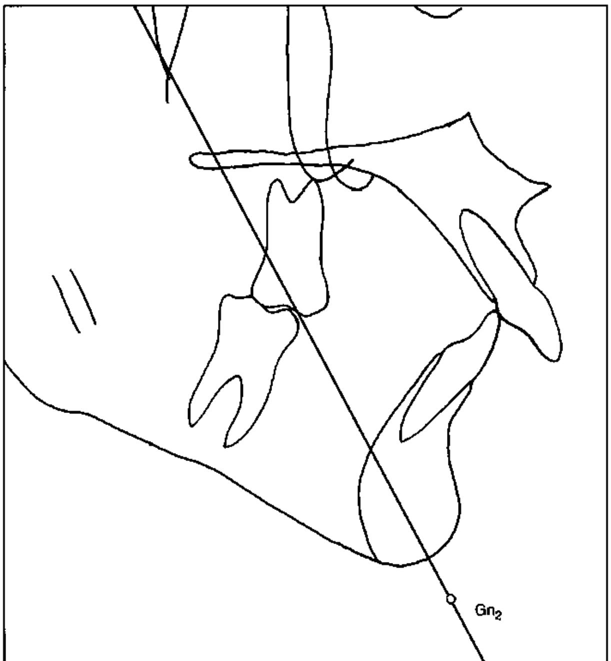


Fig C-2c New position of gnathion, shown positioned down the Y-axis.

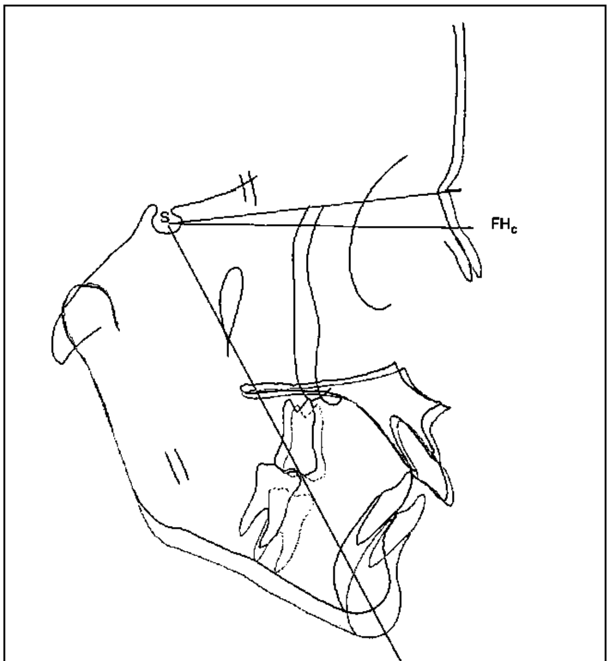


Fig C-2d Completed growth prediction with teeth "ankylosed."

Appendix D
The Occlusogram: Techniques for Planning Treatment and Evaluating Treatment Outcomes

Developed by Burstone in 1961, occlusograms are actual-sized photographs of the occlusal surfaces of the dental casts. Tracings of these occlusograms allow the orthodontist to simulate treatment in the occlusal view, or X_1-Z_1 plane, complementing the treatment-planning procedures done in the lateral and frontal views (the Y-Z and Y-X planes, respectively). These actual-sized images of the occlusal views of the dental casts can be a valuable aid in determining arch form and widths, solutions to arch length discrepancies (crowding or spacing), anchorage requirements in each quadrant for extraction cases, the presence and extent of skeletal asymmetries, and the presence and extent of tooth-mass discrepancies. Occlusograms can also be used as an aid in arch-wire construction.

Occlusograms vary depending on their use. For archival-quality occlusograms, 4- × 5-inch positive film transparencies are ideal. These transparencies allow occlusograms to be held one over the other to examine cuspal relationships; however, for treatment-planning purposes, tracings of the occlusograms are still required. For use in the orthodontic office, 4- × 5-inch black-and-white photographic prints are more useful. These photographs can be taken either with a 35-mm camera and enlarged to a 1:1 magnification or with a 4- × 5-inch Polaroid camera for 1:1 instant photographic prints. In either case, photographic prints are ideal for tracing purposes. When photographic equipment is unavailable, copies of the occlusal surfaces of the dental casts can be made on an office photocopier, where the magnification is usually 1:1.

One problem with producing 4- × 5-inch positive-film transparencies or photographic prints is maintaining the accurate orientation of the dental casts, which must be accurately trimmed in the centric relation position. The upper base and the back of the casts must be perpendicular as confirmed with a T-square. The base of the upper cast should also be trimmed so that it is parallel to the occlusal plane.

Once the dental casts have been trimmed in centric relation, they can be "grooved," that is, placed in a machine that slides the wax bite–registered casts back and forth over a height-adjustable chisel point, making a registration groove (Fig D-1). When both casts are seated on the registration track, they will be in centric relation (Fig D-2). As soon as each cast is ready to be photographed, it is placed on the registration track on the occlusostat or cast shelf (Fig D-3). A hinged plastic plate is placed on the floor of the occlusostat so that it can be raised to confirm that the occlusal surfaces of the teeth are flush with the leading edge of the occlusostat (which is also the focal length of the camera) (Fig D-4).

Both the upper and lower dental casts are photographed in this manner. When using a view camera and bellows arrangement (Fig D-4), the recommended lens has a focal length of 210 mm and can be stopped down to f:45 for the best depth of field. The distance from the leading edge of the occlusostat to the camera lens and from the camera lens to the film is 42 cm. At these settings, no enlargement is found at the level of the occlusal plane (the leading edge of the occlusostat). At 5 mm posterior to the occlusal plane, there is a 1.2% reduction in size, at 10 mm a 2.3% reduction, and at 20 mm, a 4.4% reduction.

Kodak fine-grain positive print film is used for the 4- × 5-inch positive print film transparencies. The exposure factors will depend on the individual installation; in our experience, exposure times have varied from 5 to 30 seconds depending on the lighting (incandescent to fluorescent), and the film can then be processed with x-ray developer and fixer.

For the black-and-white photographic prints, a 35-mm single-lens reflex camera can be substituted for the view camera with bellows. The sacrifice for such an arrangement is the depth of field

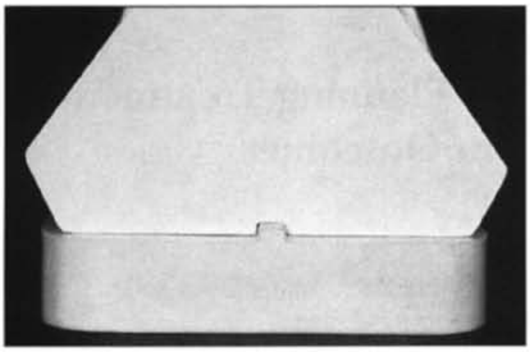


Fig D-1 Grooved lower dental cast. Once grooved, it can be placed on the registration track.

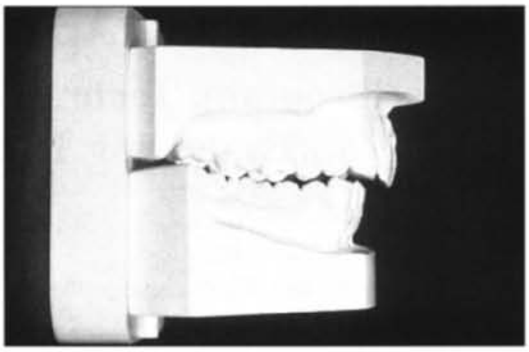


Fig D-2 Grooved upper and lower dental casts. Both casts have been grooved together in centric relation and placed on the registration track.

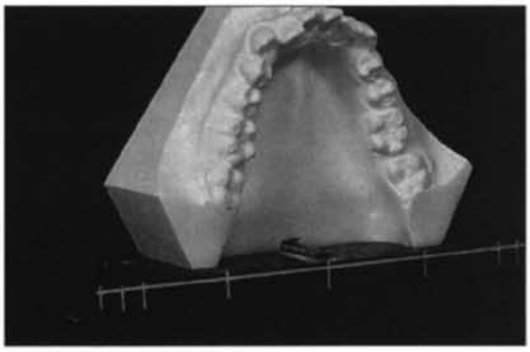


Fig D-3 Lower dental cast on the registration track of the occlusostat. The registration lines can be seen on the leading face of the occlusostat. The occlusal surfaces of the cast have also been made flush with the leading edge of the occlusostat.

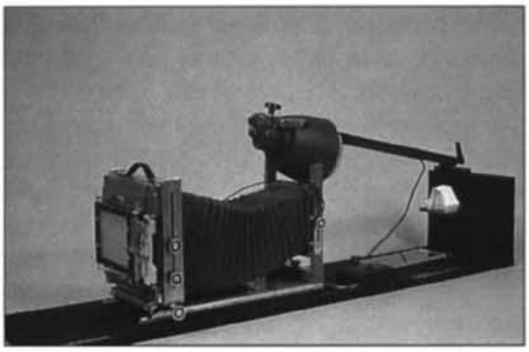


Fig D-4 Occlusograph setup. This setup can produce archival-quality occlusograms on positive print film.

but the occlusograms are nonetheless quite acceptable. A Polaroid camera can also be used for instant production of the 4- × 5-inch black-and-white prints, but be sure to wipe fixer over the prints after they have been developed. Some trial and error will be required to get the exact exposure factors. Again, both incandescent and fluorescent lighting produce occlusograms of good quality.

When photographic equipment (or experience) is unavailable, occlusograms can be produced by duplicating the occlusal surfaces of the casts on the office photocopier. For registering the occlusogram tracings when a cast-grooving machine is not available, the following methods may be used. With the wax registration positioned between the teeth of the casts, a T-square can be used to draw two lines on the heels of the casts perpendicular to the bases, about 2 to 3 inches apart. Where these two pencil lines cross over onto the lingual surface of the lower cast and the palatal surface of the upper cast, they are made a bit darker so that they will show as two dots in the photocopy. Later these dots will be used to register the occlusogram tracings laterally; the backs of the casts ("R" in Fig D-5a) will be used to register the occlusograms anteroposteriorly.

The casts are then placed on the glass plate of the photocopier, teeth side down with about 2 inches separating the backs of the casts. The usual exposure is made and the occlusograms of the upper and lower casts will be produced on the same sheet of paper. The registration dots must be clearly visible on the occlusograms.

A sheet of tracing paper is placed over the photocopy of the casts, rough side up, and is secured

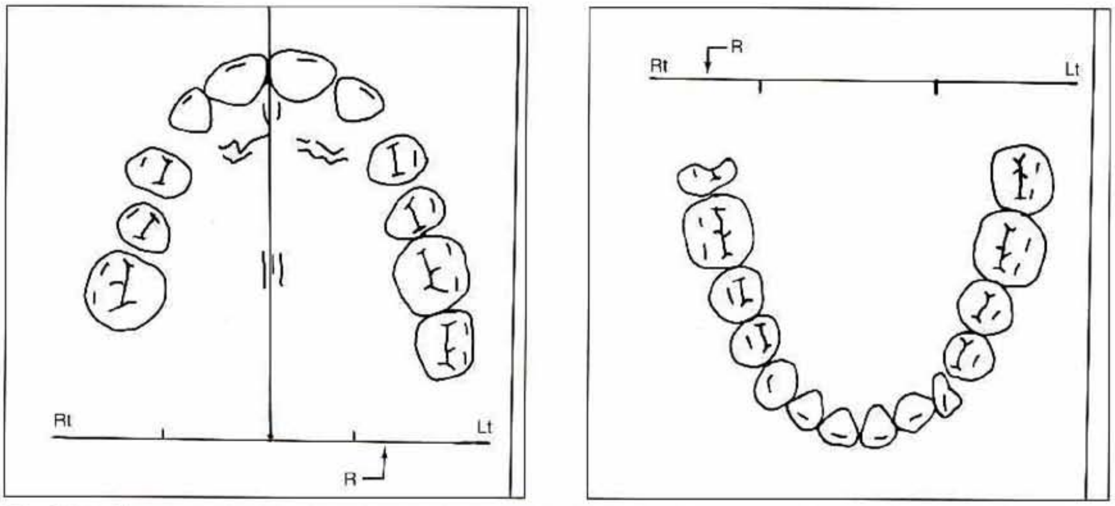


Fig D-5a Upper and lower occlusogram tracings. Both are shown with the registration dots on the backs and the registration lines (R). A midsagittal reference line drawn is also drawn on the upper occlusogram tracing.

at the corners using masking tape, which is inexpensive, easy to handle, and easily removable. Tracings are made of both the upper and lower occlusograms and include the gingival contours of the teeth; the buccal ridges, incisal edges, central grooves, and cusp tips; the incisive papilla and palatal rugae; the upper and lower registration lines ("R") from the occlusostat or the leading edge of the casts; the two penciled registration dots (for those casts without a groove); and the midsagittal reference line based on the midpalatal raphé and incisive papilla (on the upper occlusogram tracing). "R" and "L" should be marked on the right and left sides, respectively, to avoid confusing the sides later.

The upper and lower occlusogram tracings can be separated by cutting between their registration lines. Both occlusogram tracings are then superposed on their registration lines and groove or, in the absence of a cast groover, registration lines and registration dots, right on right and left on left; the lateral borders of the occlusogram tracings can be temporarily secured with masking tape.

When a cast groover is unavailable and the pencil dots are used for the lateral registration, the dots may not superpose exactly because the dots on the upper and lower casts are at different distances from the leading edge of the occlusostat. Whatever the reductions in size, the dots should still be symmetrical on both sides (ie, if it is 1 mm smaller on one side, it will be 1 mm smaller on the other side as well). With both grooved and nongrooved casts, one can ensure that the lateral registration is correct by comparing the buccal overjet or the canine overjet of the casts in centric relation; it should be the same as on the occlusogram tracings.

With the upper and lower occlusogram tracings registered and secured on the sides, the midsagittal registration line can be copied on the lower occlusogram tracing (Fig D-5b).

Growing denture bases can now be adjusted so that they will be in their predicted relationship at the end of the treatment period (2 years of growth is typical, but it could also be postsurgical or a 5-year growth prediction). For the sample patient in Fig D-5b, the 2-year growth prediction showed the A-B(OP) changing from –5.0 mm to –3.0 mm for a change of +2.0 mm. This +2 mm change in the denture base relationship means that, relative to point A, point B will be moved forward 2 mm (with growth). To move point B forward on the occlusogram tracings, mark this 2.0 mm on the upper midsagittal reference line (Fig D-5c). The

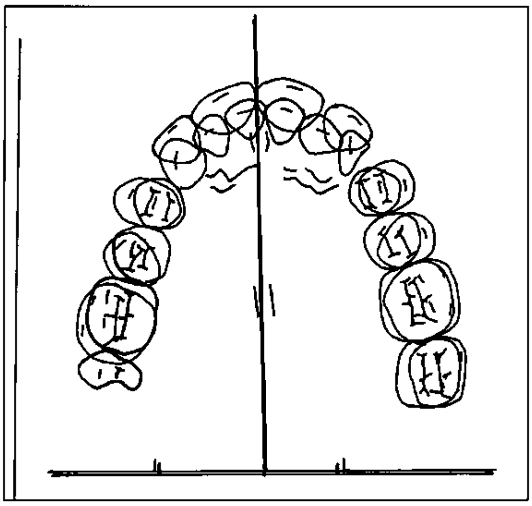


Fig D-5b The upper midsagittal reference line is transferred to the lower occlusogram tracing.

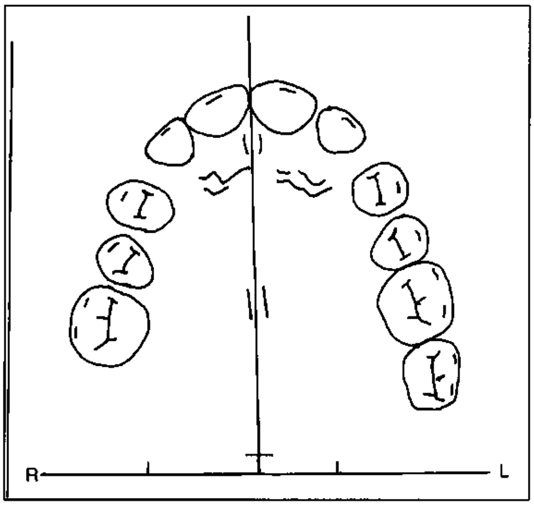


Fig D-5c Growth change incorporated in occlusogram tracings. A hash-mark is made 2.0 mm from the registration line on the midsagittal reference line.

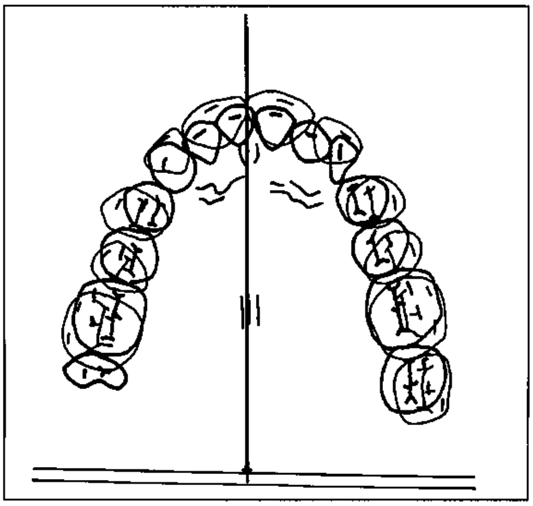


Fig D-5d Lower jaw is advanced. The lower registration line is moved up to the 2.0 mm hash-mark, the amount predicted in the growth prediction.

lower registration line is then moved forward along the superposed midsagittal reference lines to this mark (Fig D-5d). If point B moves posteriorly relative to point A (as with a mandibular setback procedure or with a surgical maxillary advancement), the before-after A-B(OP) change is marked off on the lower midsagittal reference line and the upper registration line is moved forward along the superposed midsagittal registration lines to this mark.

With the occlusogram tracings now in their predicted posttreatment relationship, the backs of the occlusogram can be cut flush (preferably with a paper cutter) and secured with noncracking mylar tape (Scotch series 2-1200, 3M, St Paul, MN). Treatment-planning procedures are now ready to be carried out on these adjusted denture bases.

Occlusogram Technique for Progress Tracings

The occlusogram technique is an excellent tool for quantifying treatment progress and for discovering the exact nature of many orthodontic problems. The photographic or photocopying technique is the same as that described for producing individual occlusograms. The bases of the casts are trimmed parallel to the occlusal plane; there might be some small error introduced if there has been a significant change in the occlusal plane cant. The before-after casts or before-progress casts are trimmed as before with the cast groover placing a groove in the upper and lower casts in the centric relation position. In the absence of a cast groover, penciled marks can be placed on the heels of the casts with the wax registration between the teeth. These penciled lines are darkened on the occlusal surfaces of the casts so they appear in the occlusogram.

Tracings are made of the original occlusograms (in black) and of the progress occlusograms (in green). On the original upper occlusogram tracing, besides the teeth, palatal rugae, and registration line and groove (or registration dots, if a cast groover is unavailable), a midsagittal reference line is drawn using the midpalatal raphé, fovea palatinus, and/or the incisive papilla.

The original lower occlusogram tracing can be folded over the original upper occlusogram tracing, superposing them on the registration lines and groove or, in the absence of a groove, the registration lines and the penciled registration dots. The sides of the occlusogram tracings are secured with masking tape to avoid any movement while the upper midsagittal reference line is copied onto the original lower occlusogram tracing; both upper and lower original occlusogram tracings now have a midsagittal reference line.

The upper progress occlusogram tracing (in green) can be superposed over the upper original occlusogram tracing (in black) using the following structures as guides for registration: the incisive papilla, the midpalatal raphé, and the palatal rugae. The original midsagittal reference line can now be copied onto the upper progress occlusogram tracing.

The lower progress occlusogram tracing can then be registered on the upper progress occlusogram tracing using the registration lines and groove (or registration lines and registration dots if a cast groover is unavailable). The upper midsagittal reference line from the upper progress occlusogram tracing can now be copied onto the lower progress occlusogram tracing.

The upper original and the upper progress occlusogram tracings can now be superposed on the midsagittal reference line, palatal rugae, fovea palatinus, and incisive papilla. Desired and undesired tooth movement can be determined by comparing the two tracings.

From the mandibular superposition of the patient's before-after headfilm or before-progress headfilm, the amount of lower incisor retraction or protraction is measured (parallel to the occlusal plane); for our sample patient, 1.0 mm of lower incisor retraction was measured. With the two tracings superposed on the midsagittal reference line, the progress tracing is then slid posteriorly 1.0 mm and the sides can be secured with masking tape. As with the upper before-after treatment superposition, desired and undesired tooth movement can be seen by comparing the two tracings.

Newer methods of digital imaging allow for accurate occlusal projections and computer manipulation of the resulting occlusograms. The occlusograms can be proportionately enlarged as necessary to increase accuracy.

Index

References with "f" denote figures

H

I

L

M

S

T

V

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90000
9 780867 153538